PB81-243180

Carbon Monoxide and Non-FTP (Federal Test Procedures) Ambient Temperature

(U.S.) Environmental Protection Agency
Ann Arbor, MI

Feb 81

U.S. Department of Commerce
National Technical Information Service
NTIS.

PB81-243180

EPA/AA/CTAB/TA/81-7

TECHNICAL REPORT

Carbon Monoxide and Non-FTP Ambient Temperature

by

Robert I. Bruetsch

February, 1981

NOTICE

Technical reports do not necessarily represent final EPA decisions or positions. They are intended to present technical analyses of issues using data which are currently available. The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments which may form the basis for a final EPA decision, position or regulatory action.

Control Technology Assessment and Characterization Branch
Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Office of Air, Noise and Radiation
U.S. Environmental Protection Agency
2565 Plymouth Road
Ann Arbor, Michigan 48105

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

BIBLIOGRAPHIC INFORMATION

PB81-243180

Carbon Monoxide and Non-FTP (Federal Test Procedures) Ambient Temperature.

Feb 81

Robert I. Bruetsch.

PERFORMER: Environmental Protection Agency, Ann Arbor, MI. Control Technology Ass essment and Characterization Branch.
EPA/AA/CTAB/TA/81-7

The objectives of this report were to summarize the available information regarding motor vehicle emissions under non-FTP temperature conditions, investigate ambient air quality data to determine the extent to which CO emissions must be reduced to achieve ambient air quality standards, evaluate vehicle test data under non-FTP temperature conditions, estimate the difference between in-use vehicle emission levels and certification laboratory emission levels, and make conclusions and recommendations based on these objectives to provide a baseline from which to consider the need for development of regulations or guidelines for motor vehicle operation under non-FTP temperature conditions and future testing procedure revisions.
KEYWORDS: *Automobiles, *Exhaust emissions.

Available from the National Technical Information Service, Springfield, Va. 22161

PRICE CODE: PC A05/MF A01

TABLE OF CONTENTS

		Page
I.	Introduction	3
II.	Conclusions	5
III.	Summary of Significant Background Studies	8
IV.	Investigation of Data From the 1975 Through 1977 Vehicle Fleet	23
V.	Discussion of Current Data	41
VI.	References	69
VII.	Appendix	73

Carbon Monoxide and Non-FTP Ambient Temperature

I. INTRODUCTION

In recent years, increasing emphasis has been placed on the importance of motor vehicle gaseous emissions under non-FTP conditions. Of special interest, particularly in this report, are the effects of ambient temperature conditions on carbon monoxide (CO) emissions from motor vehicles. Under the current Federal Test Procedure (FTP), carbon monoxide vehicle exhaust emissions are required to be below a certain level in the temperature range of 68°F to 86°F (20°C to 30°C). At ambient temperatures outside this range, particularly colder temperatures, carbon monoxide emissions from mobile sources increase dramatically. The pollutants given off during the first few minutes of cold start operation, when the vehicles control system is warming up, are known as "cold start emissions" and can account for the vast majority of all carbon monoxide emitted throughout the whole vehicle trip. These emissions may be a major factor causing National Ambient Air Quality Standard (NAAQS) violations for CO in cold weather conditions.

Ambient carbon monoxide emission levels have shown marked improvement in the counties monitored, with the greatest change evident in the East. Nevertheless, violation frequencies are still substantial, averaging from 40 to 90 days per year in the western areas studied, and from 20 to 60 days per year for the central and eastern U.S. counties [41]*.

---

*Bracketed numbers indicate reference numbers as listed in Section VI of this document.

The current NAAQS levels for CO are 9 ppm averaged over 8 hours and 35 ppm for 1 hour, neither to be exceeded more than once per year. The draft revised EPA criteria document on the health effects of CO [43] suggests that persons with stable angina (the most common form of cardiovascular disease) are probably the most sensitive population. Such persons may show adverse effects from exposure to 15 to 18 ppm CO for 8 hours. Other studies suggest that there may be no threshold concentration where stable angina patients would not be affected. Fetuses, pregnant women, and anemics may also be sensitive groups to CO exposure. However, the CO levels and frequency of exposure at which such effects would be considered significant have not been determined. The statutory CO limit for automobiles is 3.4 grams per mile (gpm) for model year 1981 and subsequent model years.

The objectives of this report are to 1) summarize the available information regarding motor vehicle emissions under non-FTP temperature conditions, 2) investigate ambient air quality data to determine the extent to which CO emissions must be reduced to achieve ambient air quality standards, 3) evaluate vehicle test data under non-FTP temperature conditions, 4) estimate the difference between in-use vehicle emission levels and certification laboratory emission levels, and 5) make conclusions and recommendations based on these objectives to provide a baseline from which to consider the need for development of regulations or guidelines for motor vehicle operation under non-FTP temperature conditions and future testing procedure revisions.

This report treats the subject of CO emissions and temperature. The work reported on in this report is only part of the overall evaluation of CO emissions from motor vehicles that is being undertaken at EPA. Factors other than temperature may also influence the CO emissions from cars. For example, the CO emissions during speed/load conditions outside those experienced on the FTP may also be important.

In addition this study proceeds under an assumption of what the CO values from the air quality monitors represent. In this report, any

difference between the CO levels recorded by the monitor and the CO levels to which people are exposed are ignored. If monitors overpredict or underpredict actual population exposure then the levels of control for mobile sources may need to be altered accordingly.

Therefore, temperature should not be considered as the only important variable.

In September 1978, a draft Advisory Circular on non-FTP Conditions was made available for public comment [38]. This draft document provided guidance to manufacturers on the policy that the EPA staff were considering for the 1980 and later model years with respect to certain aspects of Sections 202(a)(4) and 206(a)(3) of the Clean Air Act, as amended. These sections of the Clean Air Act place the burden on the manufacturers to establish that emission control systems or elements of design used in new motor vehicles or motor vehicle engines do not cause or contribute to an unreasonable risk to the public health, welfare, or safety before 1979 or later model year certificates of conformity may be issued.

Even though a vehicle meets the required standards over the Federal Test Procedure, a potential risk to public health and welfare may occur at ambient temperatures outside of the 68°F to 86°F (20°C to 30°C) range of the Federal Test Procedure and/or over different driving schedules than the FTP due to high emission levels of HC, CO and/or NOx under non-FTP conditions. The draft temperature guidelines which were made publicly available in 1978 are listed in Table A-1 of the appendix and are shown graphically in Figures 6 to 13.

II. CONCLUSIONS

The following conclusions and recommendations were made based on the analysis of the new 1980 Mobile Source Emission Factors (Mobile 2), ambient emission levels, and the in-house vehicle emission data generated in the Controlled Environment Testing Facility (CETF) at the EPA Motor Vehicle Emissions Laboratory.

1. Based on the air quality data, only about 17% of all the exceedences of the National Ambient Air Quality Standard for Carbon Monoxide occur in the temperature range around 75°F (between 67.5°F and 87.5°F - see Figure A-9) [29]. This is used here to approximate the 68° to 86°F temperature range of the Federal Test Procedure used to determine compliance with all emission standards, including the CO standard, for motor vehicles.

2. The CO emission performance of motor vehicles at ambient temperatures outside those of the FTP is of relatively greater importance than the CO emission performance of vehicles within the FTP temperature range.

   Specifically, the CO emission performance is of greatest importance in the temperature range below that of the FTP. From a National perspective, it appears that the lower bound for concern for CO temperature performance is in the range from 0°F to 20°F. There are exceedences of the NAAQS for CO at lower temperatures, but the lower bound of the temperature range indicated above does tend to recognize that special climatic conditions exist in some parts of the U.S.A. that may be approached in a more effective way by those closer to the problem, as opposed to adjusting the federal emissions standards for vehicles marketed everywhere.

   Restricting the temperature range of concern to between 0°F and 85°F, for example, captures 96% of all the NAAQS exceedences for CO, with about 2% of the exceedences below and above that range [29].

3. This report includes information on the degree of control needed to eliminate various percentages of the exceedences of the NAAQS for CO based on actual emissions data collected over a three year period from 1975 to 1977. These values of the degree of control needed are shown as a function of temperature in the report. The results presented are based on the assumption that any growth in

Vehicle-Miles-Traveled (VMT) will not affect the result. If VMT growth occurs and does affect the results, then the emission levels required will be lower than those in this report.

The CO control needed is very sensitive to the percent exceedences eliminated, especially near 100% exceedences eliminated. For example, at about 35°F, to eliminate 95% of the exceedences results in an implied emission level of 15 grams per mile at that temperature, to eliminate 99% of the exceedences implies 12 grams per mile, but to achieve the last one percent, i.e. eliminate 100% of the exceedences, implies a level of 7 grams per mile.

4. From the data that exist to date, it is clear that substantial increases in CO emissions result when vehicles are soaked at temperatures lower than those specified for the FTP.

   Most of the increased CO emissions come from the first few minutes of vehicle operation. After vehicles are warmed up, temperature does not impact their CO emissions as much. On a grams per mile basis, bag one of the FTP (the first 8.4 minutes of the 31.3 minute long test) contributes 81% of the total CO emissions at 75°F, but contributes 92% of the total CO emissions at 20°F. Cold start emissions become a larger portion of a larger value, in essence.

   For example, for the vehicles EPA has tested at its Ann Arbor Laboratory, the total CO emissions at 20°F average more than four times higher than at 75°F.

5. There are wide variations in the temperature sensitivity between vehicles. Engine type, emission control system design, and calibration strategy are all factors that influence the temperature sensitivity.

For example, two vehicles which are separated by less than 2 grams per mile at 75°F (both below the 3.4 grams per mile standard) can be almost 30 grams per mile apart at 20°F.

6. Based on test results from some prototype vehicles it can be said that suitable emission control technology appears to be available to achieve any desired level for elimination of NAAQS exceedences between the FTP temperature range and 20°F.

III. SUMMARY OF SIGNIFICANT BACKGROUND STUDIES

Several studies have been conducted in the past few years to determine the relationships between motor vehicle emissions and ambient temperature. The major reports which were analyzed as background material for this study are, in chronological order, CO Hot Spot Preliminary Investigation by the U.S. Environmental Protection Agency, Effect of Cold Weather on Motor Vehicle Emissions and Fuel Consumption II, by Nicolas Ostrouchov, A Review of Carbon Monoxide Emissions from Motor Vehicles During Cold Temperature Operation, by the Alaska Department of Environmental Conservation, Effect of Ambient Temperature on Vehicle Emissions and Performance Factors, by Gulf Research and Development Company, Temperature Correction Formulae for Adjusting Estimates of Emissions from Automobiles, by Robert L. Farrell of Vector Research, Incorporated, The Exhaust Emission and Fuel Consumption Characteristics of an Engine During Warmup - A Vehicle Study, by Donald J. Pozniak of GM, Emissions at Off-Ambient Temperatures, by W.F. Marshall and B.H. Eccleston of the Dept. of Energy, Bartlesville, Oklahoma, and Effect of Ambient Temperature, and Driving Cycle on Exhaust Emissions, W. F. Marshall of the Dept. of Energy, Bartlesville, Oklahoma.

CO Hot Spot Preliminary Investigation

The purpose of the CO Hot Spot study was to generate preliminary data on the effect of alternate soak times and temperatures prior to the

1975 Federal Test Procedure and alternate driving cycles on CO emission test results. The driving cycles run were the 1975 Federal Test Procedure (FTP) and the New York City Cycle (NYCC). Soak temperatures were either in the 10 to 25°F or 68 to 80°F ranges and soak periods ranged from 2 hours to 8 hours or overnight soaks. The directionality of these effects was known from previous studies. What was in question was the relative magnitude of each test variable on emission levels of recent production cars as well as "pre-emission control" cars.

It was found that with soak temperatures of 10 to 25°F CO exhaust emissions from bag one of the 1975 FTP increased by factors ranging from 3 to 7 over identical tests following 68 to 80°F soaks for the 1976 model cars tested. During the first 125 seconds of the 1975 FTP, CO levels as high as 350 grams/mile were emitted by these vehicles. The extreme CO emission levels observed at start up following an overnight soak decayed rapidly to fully warmed emission levels within approximately 5 minutes after start up. The decay was more rapid for the 1975 FTP than for the NYCC because the FTP is a higher speed, more strenuous cycle.

The type of emission control system on the vehicle seemed to have a strong impact on both the level of CO emissions and their distribution over the driving cycle. For example, a 1976 Granada and a 1976 CVCC Honda Civic were the two lowest CO emitters. However, bag one CO emissions represented 90% of the total 1975 FTP CO value for the Granada versus 28% for the Civic. Also, when the emissions performance of 1976 models tested is compared to the "pre-emission control cars," the results show that emission controls have not reduced CO emissions for low temperature cold starts as much as for the normal FTP temperature cold start conditions. It was found that since all of the cold start effects on emissions occur within the bag one sampling period, bags two and three are virtually independent of soak time or temperature. Thus, bag one CO emissions as a percent of 1975 FTP composite value increase as the soak temperature is lowered and/or as the soak time is increased.

On a grams/mile basis, CO emissions over the NYCC were two to three times those of bag one of the 1975 FTP for a given vehicle and soak temperature. On a grams/minute basis, the CO emission levels of bag one of the 1975 FTP were within a factor of two of the NYCC levels for any given vehicle and soak temperature. On the same grams/minute basis, decreasing the soak temperature from 77°F to 10°F to 25°F increased bag one and NYCC CO emissions by factors ranging from 1.5 to 75. This suggests that for ambient air modeling of cold climate regions, the ambient temperature can be more influential than the driving cycle.

CO emissions following a two-hour soak at 10 to 25°F are about the same as those following an overnight soak at approximately 77°F suggesting that the effect of soak time is strongly soak temperature dependent. In other words, a vehicle in cold weather can have the equivalent of multiple FTP "cold starts" in an eight hour period if soak times are two hours or more.

The use of winter grade fuels instead of the Indolene test fuel for 1975 FTPs following soak periods at 10 to 25°F had no appreciable effect on CO emissions, but 50% reductions in HC emissions were observed during the first 125 seconds of the cycle.

Finally, it was concluded that a relationship between CO emissions and engine coolant temperature may exist for a given control technology and driving cycle. Since engine coolant temperature could be adequately modelled knowing ambient temperature, soak time, possibly wind speed, and some other basic vehicle information, the engine coolant temperature may be a useful parameter for predicting vehicle emissions over a wide range of soak times and temperatures [15].

Effect of Cold Weather on Motor Vehicle Emissions and Fuel Consumption - II

This report is a continuation of the evaluation of the effect of low ambient temperature and new emission control technology on automobile emissions and fuel consumption.

Previous studies were conducted during the winters of 1972/73 and 1975/76, and indicated that exhaust emissions and fuel consumption from light duty vehicles are substantially affected by soaking temperatures.

To assess the effect of various advanced emission control systems, including Diesel powered vehicles, further cold weather testing was done on seven vehicles (more than 160 tests) over a temperature range of -20°C to 20°C (-4°F to 78.8°F) from December 1977 to October 1978. The cars in the test fleet included two identical 1978 Dodge Colts (MCA Jet engines with EGR and an oxidation catalyst), two identical 1978 Volvos (three-way catalyst with feedback K-Jetronic fuel injection), a 1978 Plymouth Fury (EGR, aspirator, and an oxidation catalyst), a 1978 Oldsmobile Delta 88 (Diesel) and a 1978 Volkswagen Rabbit (Diesel).

All test procedures, fuels, equipment, and emission and fuel consumption measurements were identical to those in the previous studies and were the same as those used in emission testing of motor vehicles for compliance with emission standards (i.e. 1975 CVS-CH), except that the off-baseline tests were conducted at various ambient temperatures instead of the standard test temperature of 20 to 30°C (68°F to 86°F). It should be noted also, that a heated sample line, which is normally used for Diesels to prevent condensation of heavy hydrocarbons, was not available for this program.

The results of the testing indicated, that for late model cars, a reduction of soaking temperature results in a considerable increase in HC and CO emissions, but the newer emission control technology is less sensitive to the soak temperature. For all vehicles, the emissions during the first phase of the 1975 CVS cycle after a cold start (bag one) account for almost all the increase in HC and CO emissions observed at reduced temperatures.

A lowering of soaking temperature resulted in an increase in fuel consumption and there appears to be a relatively greater loss with decreasing vehicle weight. The temperature sensitivity of fuel consumption in vehicles equipped with Diesel engines appears to be significantly lower than the temperature sensitivity of gasoline engines.

Emission and fuel consumption variations were correlated mathematically in terms of vehicle soaking and operating temperatures so that the resulting equations could be used to estimate temperature related changes in vehicle emissions and fuel consumption.

This study took place in Canada where the ambient temperatures are much lower than the standard emissions and fuel consumption measurement temperature range of 20 to 30°C (68 to 86°F). The average monthly minimum temperature in the most populous Canadian cities for six months of the year is -15 to 0°C (5 to 32°F). Thus, in modeling fuel consumption and emissions, Ostrouchov concludes that data from the Federal Test Procedure must be adjusted to reflect effects attributable to seasonal and geographical variations in ambient temperature [13].

A Review of Carbon Monoxide Emissions from Motor Vehicles During Cold Temperature Operation

The main objectives of this report are to evaluate the extent to which emissions affect achievement of ambient air quality standards for carbon monoxide, particularly emphasizing Fairbanks and Anchorage,

Alaska and to present methods which are currently available to reduce cold start emissions. No vehicle testing was done, but results of other studies done by EPA and assorted Canadian test programs were analyzed.

The conclusions are that at 0°F, 81% of all carbon monoxide emitted from automobiles tested in these various programs comes from the cold start phase of operation, whereas at 75°F only 36% of the carbon monoxide comes from the cold start phase, as measured by the Federal Test Procedure. Vehicles range from 1970 to 1980 prototype models, but the number of vehicles tested and their control systems are not provided in the report. The authors of the study concluded that the amount of carbon monoxide emitted during engine cold start conditions increases by 7 1/2 times as the ambient air temperature decreases from 75 to -20°F. Also, a vehicle's cold start carbon monoxide emissions are substantially increased with longer cold soak time.

It was deduced in this report that the major contributors to high carbon monoxide emissions in cold weather are 1) malfunctioning automatic chokes, 2) ignition timing and carburetor settings which are not geared to minimizing emissions but rather are set solely to improve car driveability, and 3) carburetor and intake manifold systems which do not efficiently atomize fuel before it is burned.

Four methods of CO reduction are proposed in this report including 1) use of exhaust manifold air injection, 2) use of engine preheat devices, 3) alternative engine technology and 4) engine tuneups and regular vehicle maintenance.

According to research in Canada, 1975 California vehicles with exhaust manifold air injection can reduce low temperature cold start carbon monoxide emissions by more than 60% compared to 1975 Federal vehicles.

The use of vehicle engine preheat devices reportedly has the potential to reduce carbon monoxide cold start emissions between 44% and 85%, depending on the preheat device used and the amount of preheating employed. However, it is advised in the report that energy consumption should be evaluated before selecting any preheat device as a means to achieve ambient air quality standards. Preheat devices which store excess engine heat during warm driving conditions to be later used to start a cold-soaked engine, could be further developed and considered for installation on new vehicles sold in cold weather climates.

The authors of the Alaskan report assert that alternative engine technology which has inherently low cold start emission characteristics, such as the Honda CVCC engine may offer the greatest potential for reducing cold start emissions of all possible methods reported in the current research literature.

The Alaskan study also concludes that engine tuneups and maintenance should substantially reduce overall carbon monoxide emissions through more proper timing and choke settings. The report submits, however, that research needs to be conducted to quantitatively determine the effect of maintenance on cold climate emissions [1].

Effect of Ambient Temperature on Vehicle Emissions and Performance Factors

The effect of ambient temperature on exhaust emissions, fuel economy, catalyst light off time, exhaust temperatures and driveability were studied using 14 automobiles at eight ambient temperatures which ranged from 0°F to 110°F (-18°C to 43°C). The vehicles consisted of three noncatalyst cars: a 1972 Chevrolet, a 1974 Chevrolet, and a 1977 Honda Civic. Three were 49 state vehicles: a 1977 Ford, a 1977 Plymouth, and a 1978 Buick. Five were California vehicles: a 1977 Plymouth, a 1977 Chevrolet, a 1978 Ford, a 1978 VW Rabbit (non-Diesel), and a 1979 Dodge. Three were prototype vehicles: a

1980 Mercury, a 1980 Buick, and a Datsun prototype. The studies were conducted using the 1975 Federal Test Procedure, the New York City Cycle and the Federal Short Cycle.

The cold transient phase of the FTP displayed high CO concentrations at 0°F and 20°F (-18°C and -7°C) for all of the cars. The 1980 prototype Mercury gave over 100 grams/kilometer (161 grams/mile) of CO bag one FTP emissions at 20°F (-7°C) despite having an advanced catalyst system. CO was the highest for two Chevrolet noncatalyst cars. The Honda, which was lower at 0°F and 20°F (-18°C and -7°C) than several of the catalyst cars, was also quite low at 110°F (43°C). The use of air conditioning usually increased CO, possibly as the result of increased load. The VW Rabbit showed the least change in CO emissions with ambient temperature. Overall, the Datsun prototype gave the lowest CO emissions for the cold transient phase of the FTP. The hydrocarbon and carbon monoxide variations observed at the lowest temperatures using the cold transient phase of the FTP appeared to be a function of the emission control technology used on the vehicle.

The stabilized phase of the FTP gave some very low CO emissions. The 1978 (49 state) turbocharged Buick, the 1977 (California) Plymouth, the 1978 (California) Chevrolet, the 1979 (California) Dodge, the 1980 Mercury (prototype), the 1980 Buick (prototype) and the Datsun (prototype) all had CO emissions of less than 2 grams/kilometer (3.2 grams/mile) from 0 to 80°F (-18 to 27°C). However, rich operation as indicated by high CO levels at the highest temperatures was evident in all cars, some more than others. At 110°F (43°C), the use of air conditioning often resulted in CO emissions that more than doubled.

Data from the hot transient phase of the FTP show that the 10-minute soak and the startup still had an impact at reduced temperatures. Again, higher temperatures and particularly the use of air conditioners increased CO emissions. The 1978 Chevrolet had the lowest CO emissions at all temperatures other than 110°F (43°C) where several

cars appeared to perform better. The 1980 Mercury (prototype) had the lowest CO emissions at 110°F (43°C), particularly with the air conditioners in operation.

The Sulfate Emission Test (SET), which is performed using the Congested Freeway Driving Schedule (CFDS), was run following the FTP and after a three minute engine idle period. Results showed higher CO emissions than those measured using the Highway Fuel Economy Test (HFET) but generally lower CO emissions than those measured during the hot transient phase of the FTP. CO emissions were the greatest at 110°F (43°C) and higher at the same temperature with the vehicles' air conditioning in operation.

The New York City Cycle (NYCC) is made up largely of idle conditions plus several sharp accelerations and decelerations. Even the California cars and the prototype cars have significant CO emissions when operated on this cycle. The Honda was the only noncatalyst car tested using this cycle. The NYCC, run with a warmed-up engine, gave several times the CO emissions obtained with the HFET cycle. The Honda, with its modified combustion system and no catalyst, was equal to many of the catalyst cars and much better than some at 110°F (43°C).

CO emissions were also analyzed using the Federal Short Cycle (FSC), a cycle designed for fast analysis of vehicle emissions. Of most interest is its correlation with the FTP. In general, the CO emissions obtained with the FSC were much lower than FTP composite values at temperatures below 110°C (43°C). At 110°F (43°C) CO emissions on the FSC were very high.

The light off times and the corresponding catalyst-out exhaust gas temperatures during the FTP varied widely for the different catalyst systems. Light off time was defined for this study as the time in seconds from the start of the cold transient of the FTP until the temperature of the gases leaving the catalyst exceeded those entering. The light off times for all eight ambient temperatures varied from 67

to 419 seconds and the light off temperatures ranged from about 400 to 1100°F (204 to 593°C). There was no consistent relationship between light off time and ambient temperature. The maximum exhaust gas temperature measured was 1462°F (794°C). There were larger differences in exhaust gas temperatures between the various catalyst systems than there were between test procedures or ambient temperatures.

A considerable number of driveability problems occurred at 0 and 20°C (-18 and -7°C) using the cold transient phase of the Federal Test Procedure. However, some driveability problems were encountered at higher ambient temperatures and with other test cycles. Driveability problems usually increased most of the exhaust gas emissions [4].

Temperature Correction Formulae for Adjusting Estimates of Emissions from Automobiles

This analysis, conducted by Vector Research, Inc., was intended to provide formulae, referred to as correction formulae, which could be used to estimate the emissions of regulated pollutants at temperatures other than those used in the standard Federal Test Procedure. Data were analyzed on a bag by bag basis from more than 100 U.S. and Canadian vehicles over a 0 to 110°F temperature range to determine the effects on CO emissions of 1) model year (1967 to 1980), 2) standard (California or 49-state Federal), 3) emission control system (engine modifications, air pumps, three-way and oxidation catalysts, carburetors and fuel injection) and 4) inertia weight. Emission control systems were analyzed in the following configurations: no controls, EM, EM/AIR, OC, OC/AIR, TWC, TWC/FI, TWC/OC, and TWC/OC/FI. The temperature effects observed were evaluated by comparing the CO emission levels at low temperatures (0 to 67.5°F) and high temperatures (86.5 to 110°F) to those observed at the standard FTP temperature.

Temperature effect equations were fit to each of the three bags. From the data, the equations showed increases in emissions at low

temperatures for bags one and two, with little or no effect for bag three at low temperatures, and decreases in emissions at high temperatures for bag one, with increases at high temperatures for bags two and three.

No trend was shown toward increasing or decreasing bag one CO emissions since the 1967 model year at temperatures higher or lower than the FTP temperature (analyzed in the report as the natural logarithm of emissions of CO in grams per mile at the non-standard temperature divided by the natural logarithm of CO emissions in grams per mile at the standard temperature). However, bag one CO emissions at low temperatures have been consistently higher than bag one CO emissions at the FTP temperature. Conversely, bag one CO emissions at high temperatures have been consistently lower (with the exception of 1977 California vehicles) than bag one CO emissions at the FTP temperature. The maximum cold temperature bag one CO emissions came from 1976 Federal vehicles with 4 1/2 to 5 times as much bag one emissions in the 20°F range as in the FTP temperature range. Among vehicles tested at 0°F, 1977 Federal cars exhibited bag one CO emissions 7.6 times greater than they did at FTP temperatures. The minimum cold temperature bag one CO emissions occurred in 1970 Federal vehicles with CO levels at 20°F 1.64 times higher than those at FTP temperatures. Bag one CO emissions at 110°F ranged from 0.40 (for 1970 Federal vehicles) to 1.63 (for 1977 California vehicles) times the CO emission levels at FTP temperatures. These ratios are again based on the natural logarithm of grams per mile CO emissions at non-standard to standard FTP temperatures.

Most bag two CO emissions were not greatly increased as the temperature got farther away from either end of the FTP range with the exception of 1978 Federal vehicles. At 110°F, these vehicles exhibited a tenfold increase in CO emissions over tests at FTP temperatures.

Bag three CO emissions at low temperatures did not vary significantly from FTP temperature levels for all model years in the data base. The effect was slightly more pronounced at higher temperatures. Again, 1978 Federal vehicles were the worst case emitting 3.25 times as many CO emissions at 110°F than at FTP temperatures.

In very few cases did the effect of standards (California or Federal) make a difference on temperature response of CO emissions. In those that did, it was found that California vehicles showed less effects of temperature, with the ratio of California vehicle emissions at any temperature to those at FTP temperatures being smaller than those exhibited by Federal vehicles. Perhaps this is due to the fact that prior to 1980, the California standard (9.0 CO) was stricter than the Federal standard (15 CO).

Data were examined for eight different categories of emission control technology to determine their respective effects on CO emissions at different temperatures. Surprisingly enough, the worst bag one CO emitter at both low and high temperatures relative to FTP CO emissions were systems equipped with three-way plus oxidation catalysts with fuel injection. Very few data were available for this system compared to the other seven systems analyzed. The next worst systems, in terms of bag one CO emissions, were systems equipped with three-way catalysts and a carburetor at temperatures below the FTP, and systems equipped with oxidation catalyst without an air pump at temperatures above those of the FTP. The lowest CO emitting systems from bag one at low temperatures were vehicles with three-way catalysts and fuel injection and vehicles with engine modifications and air pumps. No data were available for these two systems at high temperatures. The best systems of those with data available at high temperatures were vehicles with oxidation catalysts and air pumps and vehicles with three-way catalysts and a feedback carburetor. Vehicles with no emission control system at all exhibited high CO emissions at all temperatures compared to their emissions at FTP temperatures.

Cases were examined in which the temperature response was assumed to vary linearly with vehicle inertia weight. Statistically significant effects were found to exist for below FTP temperature CO emissions in bags one and two. The effects were measured in terms of the change in a temperature response coefficient per thousand pounds of increased inertia weight from a mean value of 3760 pounds. CO emissions were found to increase slightly with increased inertia weight in bag one, and decrease slightly with increased inertia weight in bag two. No effect of inertia weight on CO emissions at temperatures above the FTP range could be found [2].

The Exhaust Emission and Fuel Consumption Characteristics of an Engine During Warmup - A Vehicle Study

The purpose of this study was 1) to determine the effects of air-fuel ratio and spark advance on the emissions measured during warmup of a vehicle when operated in accordance with the FTP, and 2) to identify reasons for differences in levels of emissions measured during warmup compared with those measured when the vehicle was fully warm.

Testing was conducted using a vehicle equipped with a 5.0 liter engine, three speed automatic transmission, EGR, and an oxidation catalyst. A modified carburetor was used on the test vehicle for this project. The principal observations made are 1) during warmup, minimum HC and CO tailpipe emissions occurred near air-fuel ratios of 14.5 and 16, respectively, 2) after warmup, minimum HC was at about 16.5 air/fuel ratio and minimum CO was at an air/fuel ratio of 16 or leaner and 3) compared with fully warm operation, operation during warmup increased fuel consumption at all air-fuel ratios and increased HC and CO emissions at air-fuel ratios only leaner than about 14 and 16, respectively. Spark retard during warmup did not significantly affect HC emissions or fuel consumption, but decreased NOx emissions and driveability, and increased CO emissions at lean air fuel ratios only.

The primary conclusions reached from the study are 1) during warmup on the FTP, the engine air-fuel ratio should be maintained in the 14.5 to 16 range as soon as practicable within the constraints of acceptable vehicle driveability. Disregarding driveability, an air-fuel ratio of 16 offers the best compromise of emissions and fuel economy. 2) Within the range of variables used in the study, the time required to attain catalyst reaction temperature is not measureably affected by engine air-fuel ratio. 3) Gas phase oxidation in the exhaust system upstream of a catalytic converter can be a major reason for lower HC and CO emissions from a vehicle when fully warm than when cold [7].

Emissions at Off-Ambient Temperatures

The Department of Energy's (DOE) Bartlesville Energy Center (BETC) was selected in an interagency agreement between DOE and EPA to conduct tests on a fleet of vehicles to determine a baseline for automobile emissions at a variety of operating temperatures. All tests were conducted in a climate-controlled chassis dynamometer facility at BETC.

A fleet of twenty-five 1970 model-year vehicles had been previously acquired and tested by Automotive Testing Laboratories, Inc., under contract with the Motor Vehicle Manufacturers Association. The vehicles were selected to represent the 1970 model-year nationwide sales mix. Each vehicle was tested on the 1975 FTP, the HFET and the NYCC sequences. No additional load was applied for vehicles equipped with an air conditioner.

The fleet average FTP CO emission rate was 21 grams/mile at 75°F. The current 3.4 grams/mile standard is a 90% reduction from fleet average 34 grams/mile CO as measured by the revised 1975 FTP [40]. HC and CO emissions increased significantly as the test temperature was decreased from the standard ambient of 75°F to 25°F. The increases were 0.7% and 1.5% per 1°F decrease for HC and CO, respectively, over the EPA urban FTP driving cycle.

In the 1975 FTP test cycle, variation from a standard ambient temperature of 75°F had little effect on emissions over the stabilized and hot transient phases. Essentially all of the increases in emissions of HC and CO associated with lower ambient temperatures were incurred in the cold transient phase.

FTP nitrogen oxide emissions increased slightly with increasing temperature, approximately 6% greater at 100°F than at 75°F.

Emissions of all three regulated pollutants (on a grams per mile basis) were greater for the NYCC than for either the FTP or highway driving cycles.

Fourteen of the 25 cars in the fleet had operational air-conditioning systems and were tested on the FTP, HFET and NYC cycles at 75°F and 100°F, both with and without air-conditioning. The use of air-conditioning caused moderate increases in HC and CO emissions in the FTP and highway cycles. HC and CO increased by 20% and 60%, respectively, during the NYCC at 100°F. This is due to the additional load placed on the engine during idle, a mode which comprises more than one third of the entire NYCC. The effect on NOx was much greater and fairly consistent for all three driving cycles. The increased power requirement could be the source of this increase [5].

Effect of Ambient Temperature and Driving Cycle on Exhaust Emissions

This report is a follow-up study on the baseline examination described in the previous paper, Emissions at Off-Ambient Temperatures. In that paper, a fleet of 25 1970 model year vehicles were tested to form a baseline with which to compare later model vehicles. In this report, five more 1970 MY vehicles were tested plus seven late model production vehicles for a total of 37 vehicles in the test fleet. The late model production vehicles consist of three three-way catalyst vehicles, two Diesel vehicles, one stratified charge vehicle and one turbocharged vehicle.

Emissions were determined at a variety of ambient temperatures to evaluate the emission trends of new technology vehicles relative to those of the 1970 MY vehicles.

When emissions at different temperatures are referenced to the 75°F FTP case, the results appear to show that temperature extremes have a greater deleterious effect on emissions performance of the current production fleet than the baseline fleet. CO emissions in grams/mile were 3.3 times higher at 25°F than at 75°F for the current fleet compared to 1.8 times higher for the baseline fleet. However, if the results are referenced to the emissions "standards" applicable to the fleet, the current production fleet's performance appears to be markedly better than that of the baseline fleet. (The standard for 1970 baseline vehicles was assumed to be 34 grams/mile). Absolute and percentage differences in emission rates between the two fleets indicate that overall, the current fleet's emission levels are about 70% less than the baseline fleet at 25°F [39].

IV. INVESTIGATION OF DATA FROM THE 1975 THROUGH 1977 VEHICLE FLEET

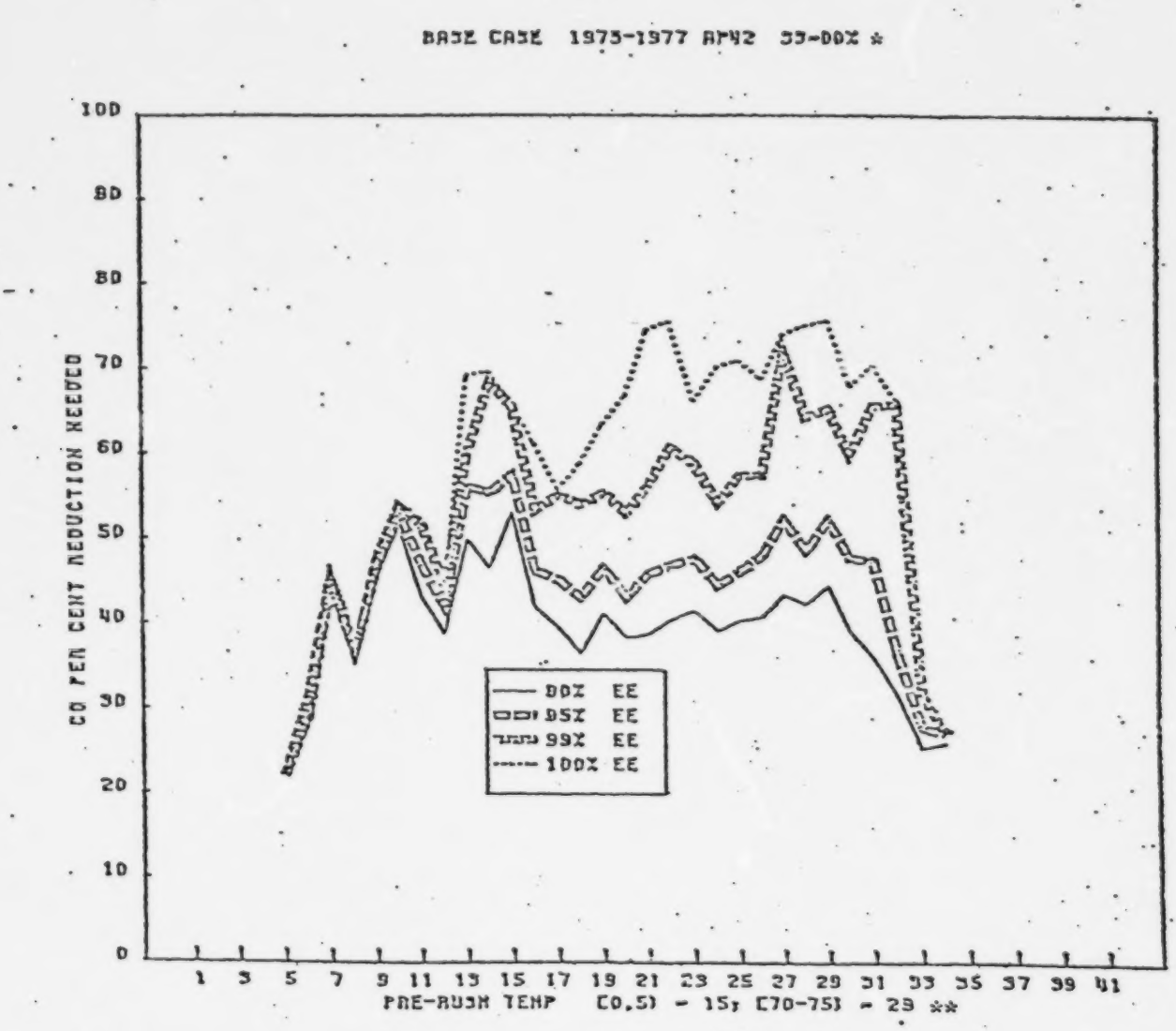
The EPA Mobile Source Emission Factors data of March 1978, hereinafter referred to as Mobile 1, were analyzed in combination with data from the Storage and Retrieval of Aerometric Data (SAROAD) and the National Weather Service (NWS) data bases to determine the certification emission levels at specific temperatures that would have to be attained by vehicles to eliminate 90 to 100% of the exceedences of the 8 hour 10mg/m^3 National Ambient Air Quality Standard (NAAQS). The same analysis was also done using the new 1981 Mobile Source Emission Factors data, hereinafter referred to as Mobile 2.

Ambient Data from the SAROAD and NWS Data Bases

Data from the SAROAD data base provided observations of ambient CO concentrations at various locations as functions of date and time of day. The NWS data provided concurrent ambient temperatures that could

FIGURE 1

MOBILE 1



---

* SS = 00% means no stationary source contribution to total CO emissions.
SS = 05% means stationary sources amount to 5% of total CO emissions.

** Interval 15 corresponds to the 0-5°F temperature range.
Interval 29 corresponds to the 70-75°F temperature range.
The specified temperature range is an average of the three hours immediately preceeding the rush hour that preceeds the ending hour of the associated 8-hour average concentration.

FIGURE 2

MOBILE 1

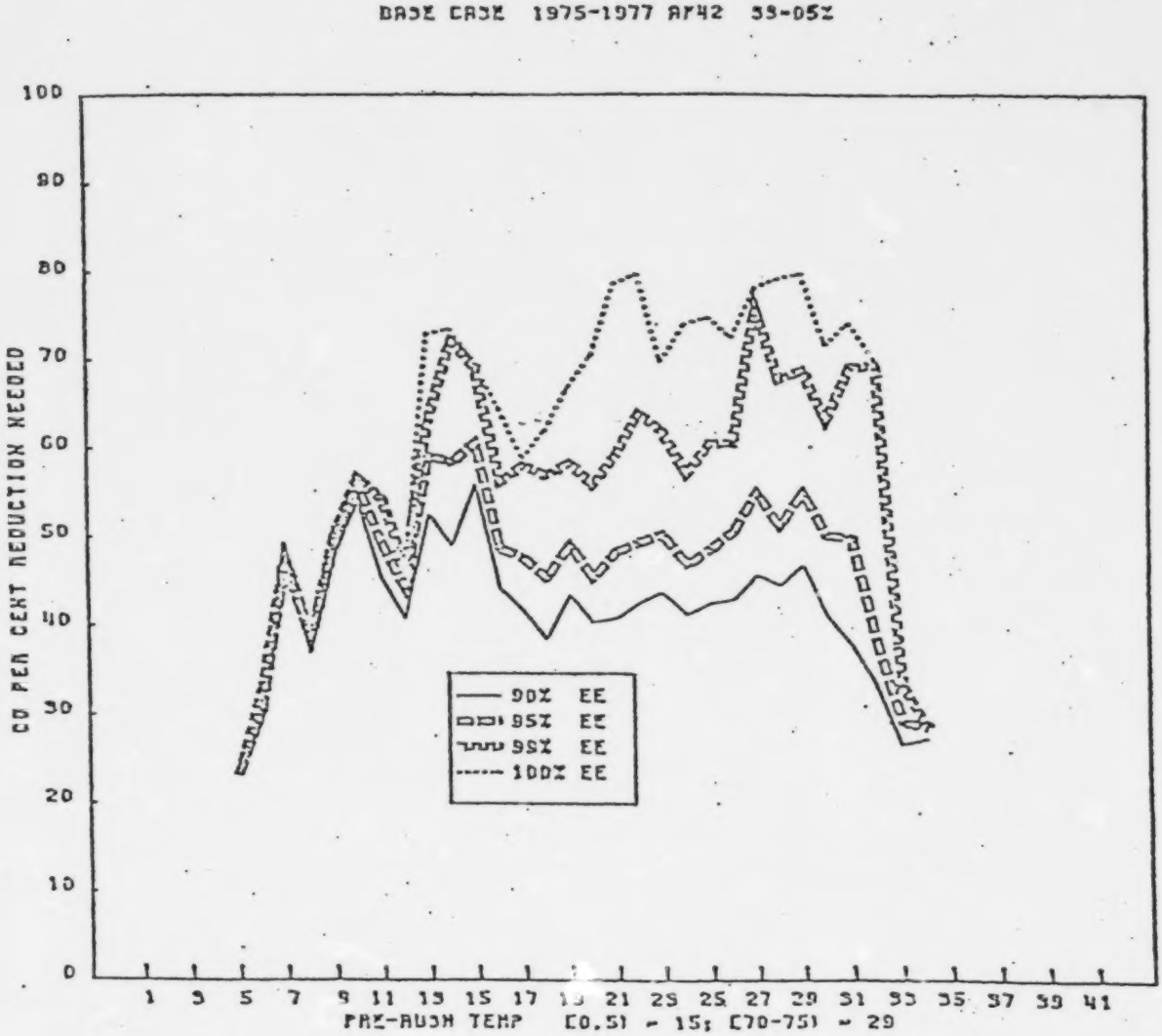
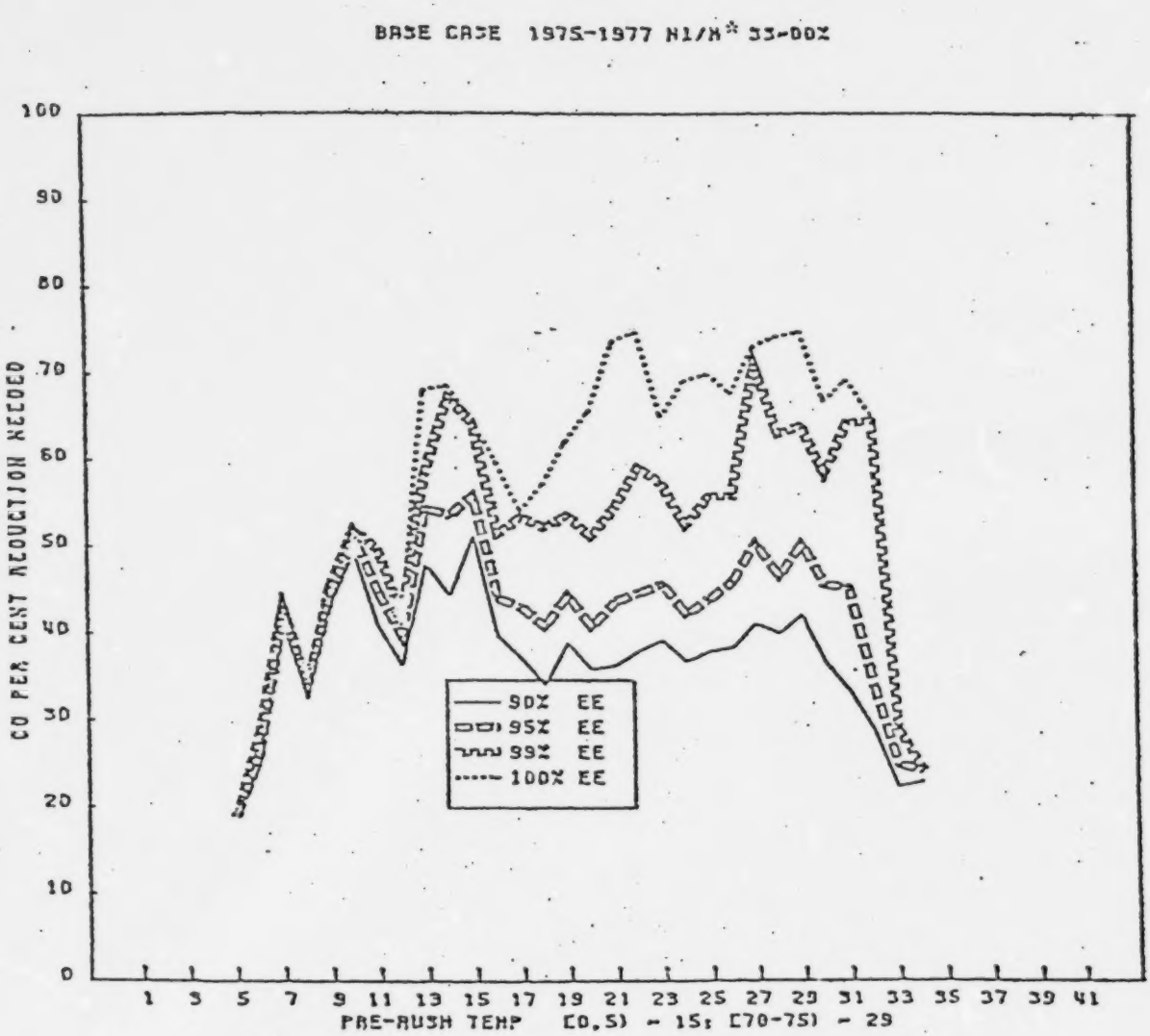


FIGURE 3

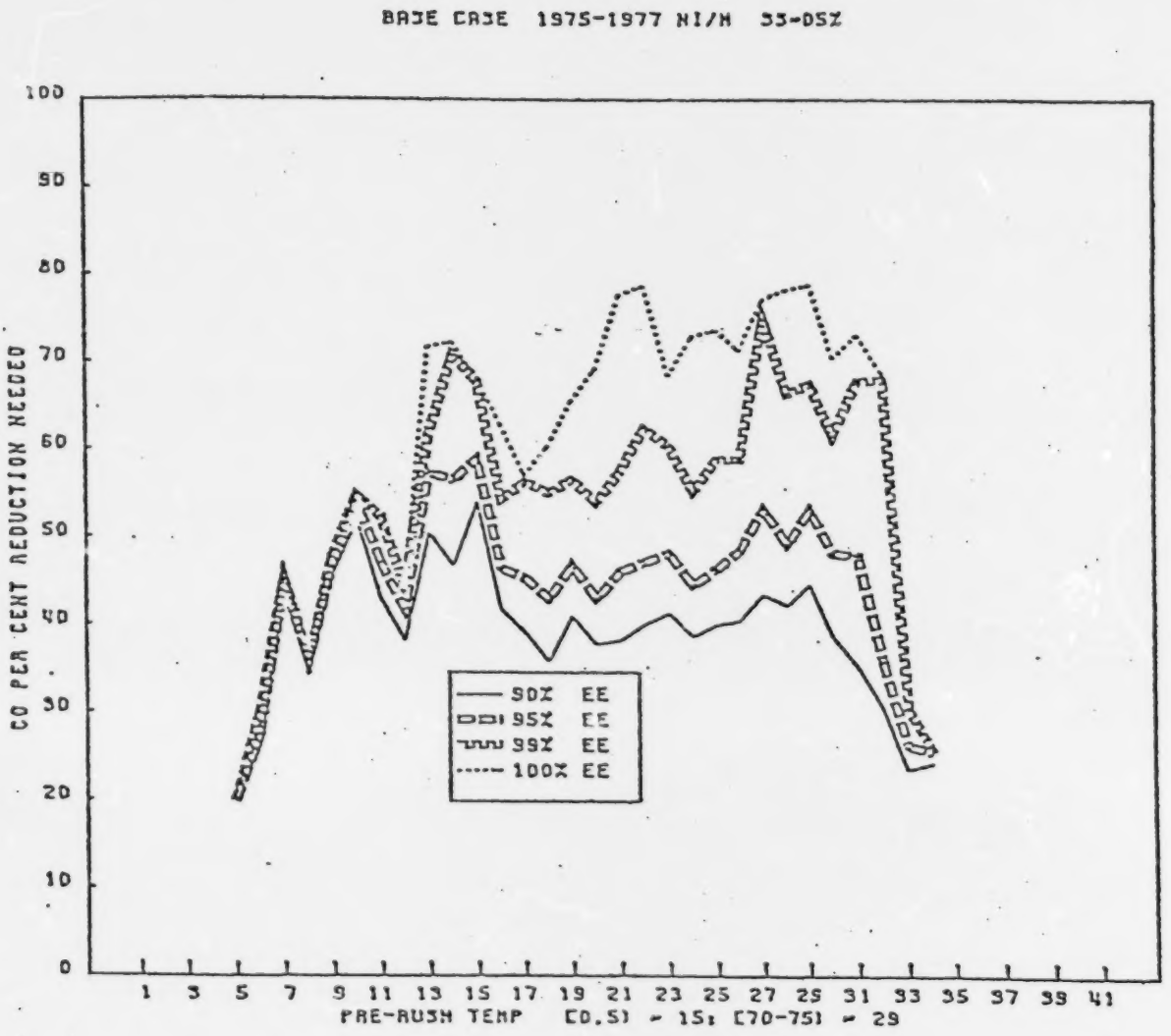
MOBILE 2



* Non I/M. Inspection and maintenance benefits not included.

FIGURE 4

MOBILE 2



be related to these ambient CO monitoring locations. Figures 1 to 4 show the percent by which each eight hour average ambient CO level in over 50 cities must be reduced to eliminate exceedences of the standard based on Mobile 1 and 2 with stationary source CO contributions of zero and five percent. Cities were chosen on the basis of having a large number of 8 hour average concentration values in one year that exceeded 10 mg/m^3. In general, the 50 cities with the greatest number of exceedences have been included. The dotted line indicates the per cent reduction in ambient CO needed to eliminate 100% of the NAAQS exceedences. The solid line indicates the level at which 90% of exceedences will be eliminated. Temperatures range from -50°F to 110°F in five degree intervals. Interval number 15 includes all eight hour averages that were associated with a zero to five degree (°F) temperature range. Interval number 29 covers the 70-75°F range. Data from SAROAD for the three year period from January 1, 1975 to December 31, 1977 were used in the analysis. At the temperature extremes, comparatively few data points determine the position of these curves. Fairbanks, Alaska, accounts for most of the very low temperatures and Phoenix, Arizona, accounts for most of the very high temperatures. The highest eight hour average CO concentration confirmed for the 1975-1978 period is 38.5 mg/m^3. (A 74 percent reduction in this level is required to meet the 10 mg/m^3 standard.) Concentrations reported which were above the 38.5 mg/m^3 level were excluded from the SAROAD data used in this analysis.

Ambient CO concentrations were recorded on an hourly basis from which running eight hour CO averages were determined. Table 1 shows an example of how running eight hour averages were taken from hourly CO data to determine eight hour average CO exceedences of the applicable NAAQS. In this example 9 ppm is the assumed standard and eight hour average concentrations above a 9 ppm are said to be exceedences of the standard. For the Mobile 2 (new emission factors) analysis, a 9 ppm (10.35 mg/m^3) standard was also assumed.

TABLE 1

Example of How Running Eight Hour Averages
Are Determined from Hourly CO Data

CONSECUTIVE 1-HR AMBIENT CO OBSERVATIONS (ppm)	RUNNING 8 - HR AVERAGE (ppm)	9ppm 8 - HR AVERAGE EXCEEDENCE?
12	-	-
11	-	-
10	-	-
8	-	-
7	-	-
6	-	-
5	-	-
5	8.0	no
6	7.3	no
6	6.6	no
6	6.1	no
8	6.1	no
10	6.5	no
13	7.4	no
15	8.6	no
15	9.9	yes
16	11.1	yes
17	12.5	yes
18	14.0	yes
17	15.1	yes
16	15.9	yes
16	16.3	yes
16	16.4	yes
16	16.5	yes

If you take the set of exceedences and reduce each one to the standard, the amount or fraction by which each exceeds the standard is the "percent reduction needed" to achieve that standard. Table 2

shows an example of how percent reduction needed to achieve a 9 ppm CO level was calculated from a given set of exceedences. To eliminate 100% of the exceedences a percent reduction needed associated with the maximum exceedence, or 45.5%, must be achieved. Figure 5 shows the relationship between percent reduction needed and percent exceedences eliminated for this example. A line of equality is shown to demonstrate that the percent exceedences eliminated is greater than the percent reduction needed.

TABLE 2

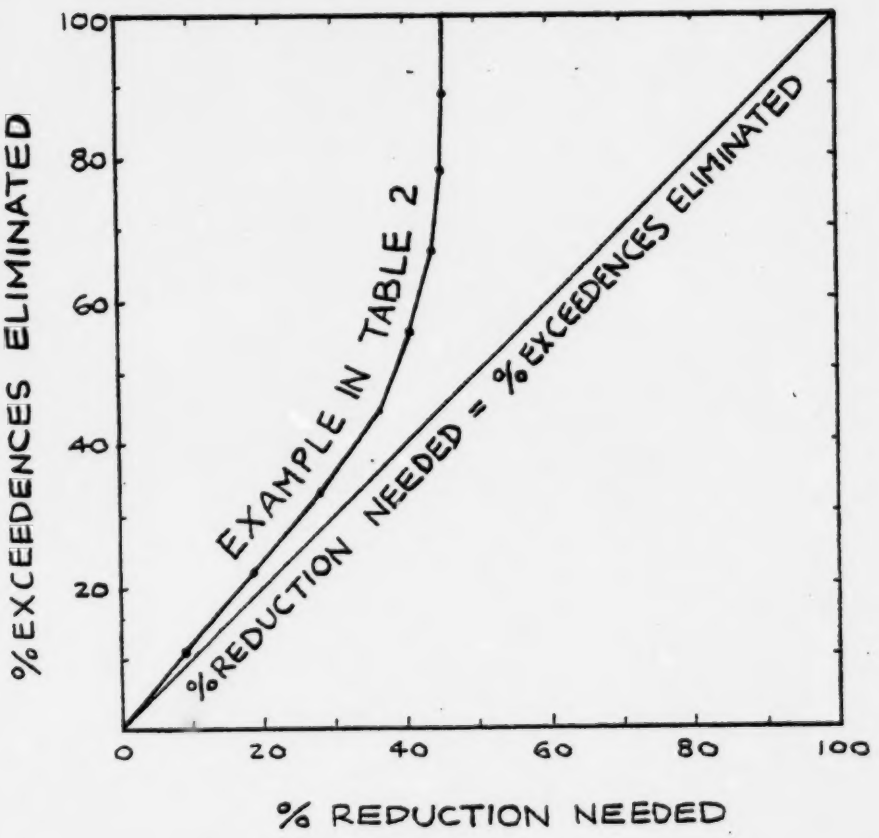
Example of How Percent Reduction Needed and Percent Exceedences Eliminated Are Calculated From a Given Set of Exceedences To Meet a 9ppm Ambient CO Level

SET OF EXCEEDENCES (ppm)	(%) REDUCTION NEEDED	(%) EXCEEDENCES ELIMINATED
16.5	45.5	100
16.4	45.1	89
16.3	44.8	78
15.9	43.4	67
15.1	40.4	56
14.0	35.7	44
12.5	28.0	33
11.1	18.9	22
9.9	9.1	11

All of the ambient temperatures in this analysis are called "pre-rush hour" temperatures. Pre-rush hour temperature means the temperature at which the vehicle is soaked prior to the morning or evening rush hour. So all exceedences in a given day are assigned a corresponding temperature which is the average ambient temperature for the 3 hours which immediately precede the rush hour. This, we believe, appropriately assigns CO exceedences to the temperature during the

FIGURE 5.

PERCENT REDUCTION NEEDED VS PERCENT EXCEEDENCES ELIMINATED FOR EXAMPLE IN TABLE 2.



period of time immediately before the cold starts and vehicle operation during the rush hour. The morning rush hour is taken from 0601-0900 Local Time (LT); the evening rush hour extends from 1601-1900 LT. Daylight Savings Time (DST) begins on the last Sunday of April and ends the last Sunday of October. A complication which arose was that not all locations in the U.S. adhered at that time to DST uniformly. Nevertheless, for computation ease DST was assumed to apply to all areas from May through October.

Vehicle Emissions Data

Tailpipe CO emissions data were collected from the data bases used in the low altitude Federal versions of Mobile 1 and Mobile 2. The collected data were from vehicles and engines which correspond to the light duty vehicles (automobiles) and the mobile source fleet which were in-use during the period from January 1, 1975 through December 31, 1977. The in-use CO emissions were calculated for the temperature range of concern by the computer programs in Mobile 1 and 2. The calculated emissions were then reduced by the percent reductions needed to eliminate exceedences of the NAAQS CO standard at the same temperature (as shown in Figures 1 through 4). This analysis was done first assuming only improvements in CO emissions from light duty vehicles (LDV) and then assuming proportional improvements in fleet emissions. The graphs labeled LDV assume that LDV emissions completely represent the fleet. The graphs labeled FLEET assume that "composite" emissions represent the fleet. The CO levels which must be attained by in-use vehicles to eliminate the NAAQS exceedences are plotted for pre-rush hour temperatures ranging from 0°F to 100°F in five degree intervals (see Figures A1-A8). It is important to note that no high altitude data were included, and that VMT growth was not considered.

The analyses of Mobile 1 and 2 were done for two separate cases, one which assumed that 5% of the CO was attributable to stationary source (ss) contributions and one which assumed no stationary source contribution. The National Emission Inventory Report [31] indicates

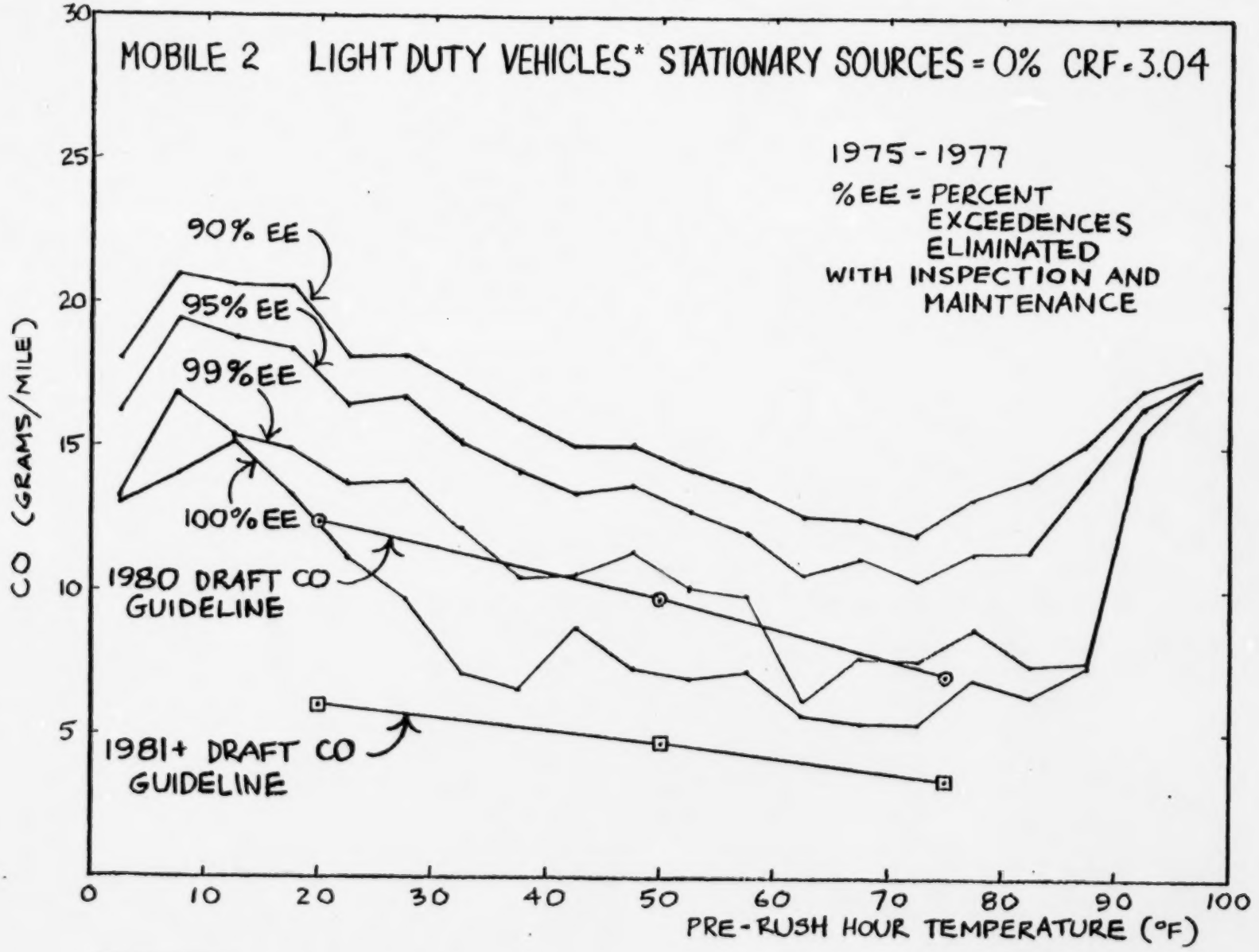
that the average stationary source CO contribution of the 146 worst counties is approximately 15% [31]. This stationary source contribution takes into account, however, "uncontrolled" mobile source contributions such as off-highway gasoline vehicles, off-highway diesel vehicles, rail, vessels and aircraft in addition to the true stationary sources. In order to meet the NAAQS, the regulated mobile sources, which consist of light duty vehicles, light duty trucks, motorcycles, heavy duty gasoline vehicles and heavy duty diesel vehicles, must be controlled to lower CO levels to account for the uncontrolled mobile sources and the true stationary source contributions.

In modeling carbon monoxide concentrations, stationary sources are heavily discounted to account for their normal dispersion [35]. Discount factors of 80% for stationary area sources and 100% for stationary point sources such as power plants are used. These factors were selected after considering the results of dispersion models for point sources and reviewing the relationship between traffic density and CO levels in several situations. Using these discount factors, the stationary source contribution is assumed to be about 2% or 3%. Thus, EPA used 0% and 5% in the analysis as the lower and upper bounds for the stationary source contribution.

As a final treatment of the data, a certification to in-use factor (CRF) was applied to the in-use CO emissions levels which must be attained to eliminate NAAQS exceedences in order to compare these emissions levels with data from EPA certification type testing and from the EPA's Controlled Environment Testing Facility (CETF). The CETF is an in-house testing facility at the Motor Vehicle Emission Laboratory (MVEL), Ann Arbor, Michigan. The latest EPA estimates for certification to in-use factors, based on Mobile 2 for low altitude, 49 state fleet emissions (and assuming a 3.4 CO light duty vehicle standard) are 3.04 (with inspection and maintenance programs) and 5.53 (without inspection and maintenance) [36]. The predicted Mobile 2 50K CO emission level for 1983 and future model year vehicles without

inspection and maintenance programs is 18.80 grams/mile. Dividing this "in-use" number by the 3.4 grams/mile CO "certification" standard yields a CRF of 5.53. Mobile 2 estimates that inspection and maintenance programs are effective in reducing CO emissions levels by 45%. The CRF assuming inspection and maintenance programs is therefore 55% of the CRF without inspection and maintenance, or 3.04. Plots of CO emission levels versus pre-rush hour temperature for Mobile 2 with these CRF's applied are shown in Figures 6 to 13 for 90, 95, 99 and 100% of the NAAQS exceedences eliminated.

FIGURE 6.



*Assumes LDV is the entire fleet.

FIGURE 7.

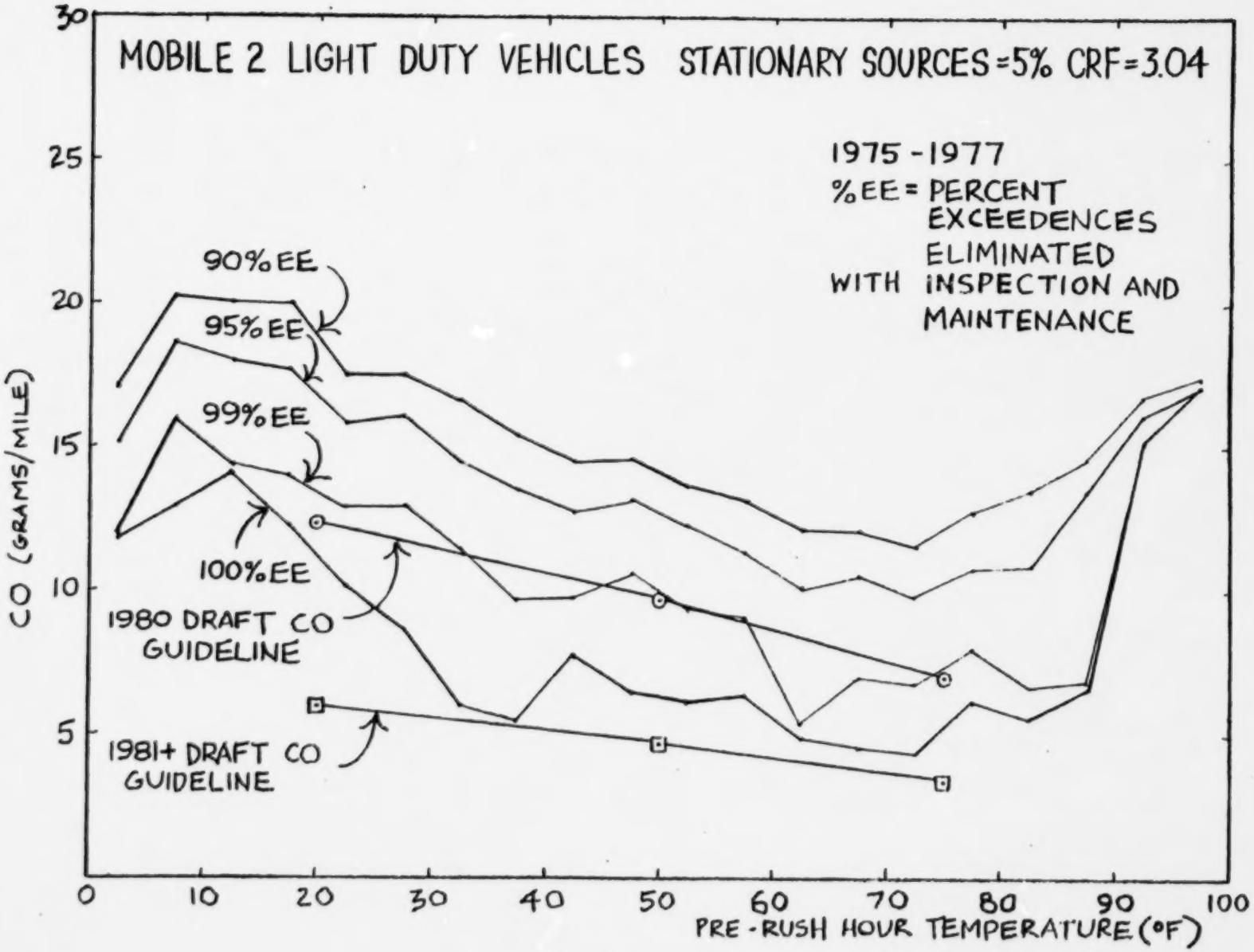
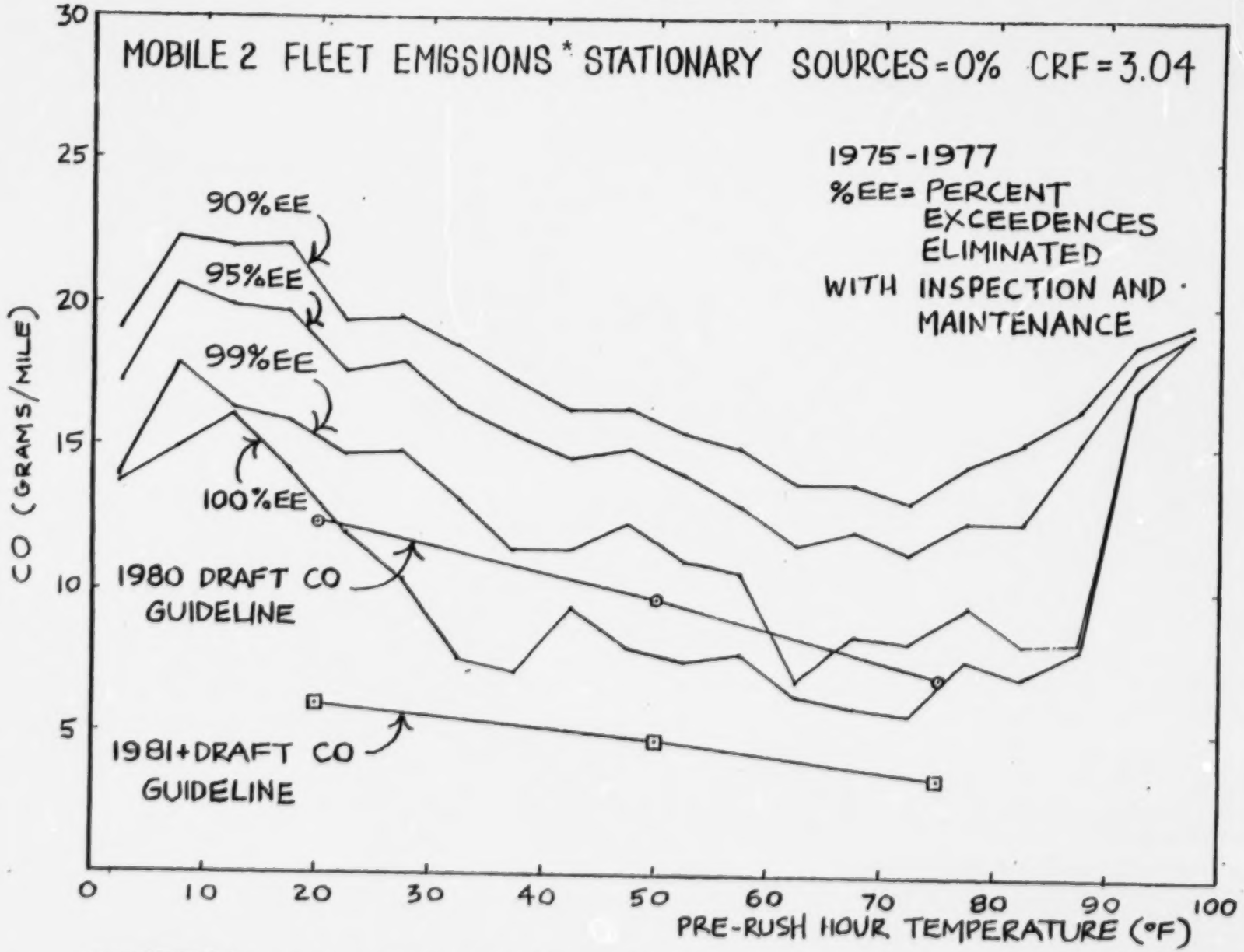

MOBILE 2 LIGHT DUTY VEHICLES STATIONARY SOURCES=5% CRF=3.04
1975-1977
%EE = PERCENT EXCEEDENCES ELIMINATED WITH INSPECTION AND MAINTENANCE
90%EE
95%EE
99%EE
100%EE
1980 DRAFT CO GUIDELINE
1981+ DRAFT CO GUIDELINE
CO (GRAMS/MILE)
PRE-RUSH HOUR TEMPERATURE (°F)
30
25
20
15
10
5
0
10
20
30
40
50
60
70
80
90
100

FIGURE 8.



*Assumes identical CO reduction for all segments of the vehicle fleet.

FIGURE 9.

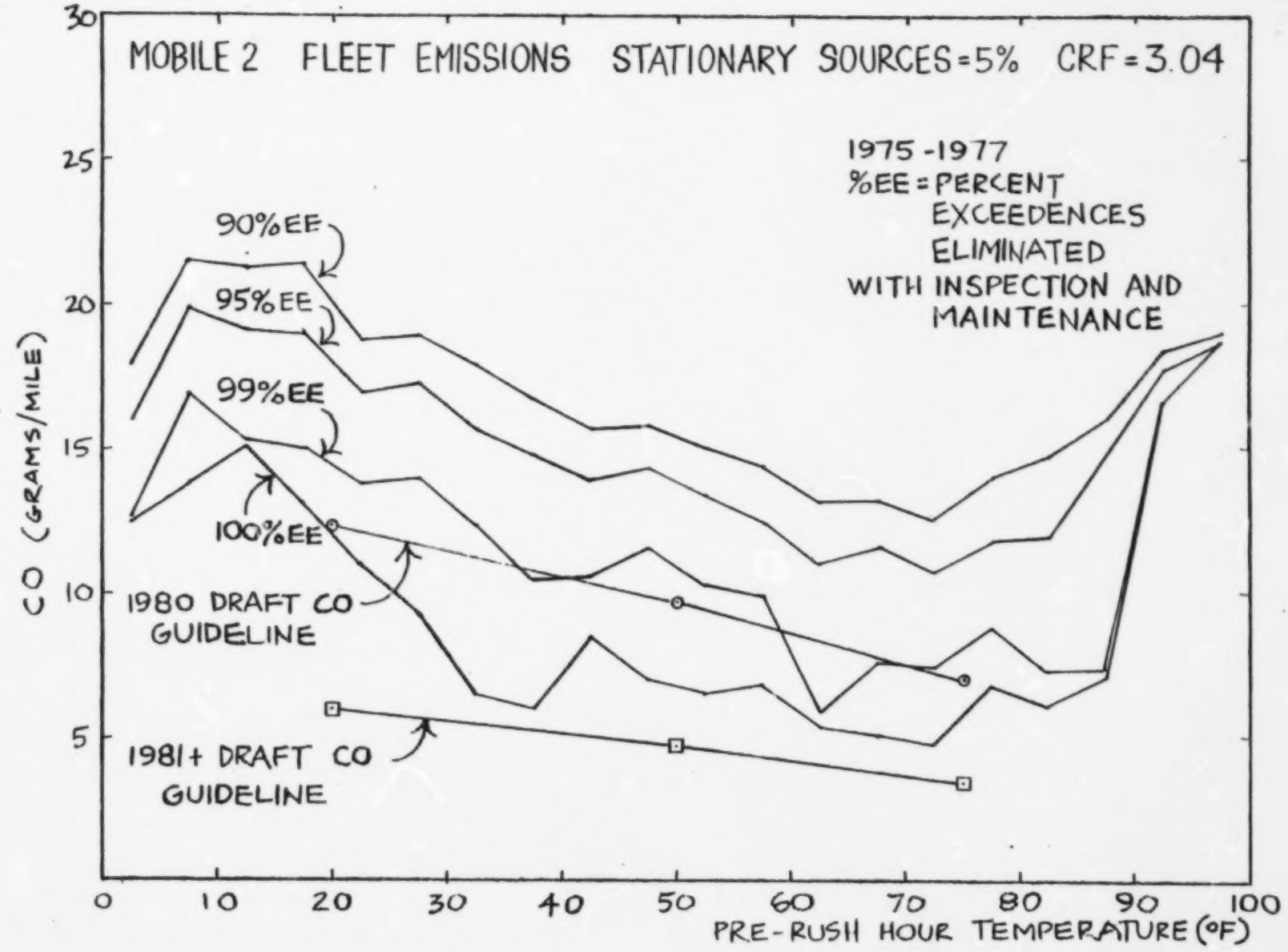

MOBILE 2 FLEET EMISSIONS STATIONARY SOURCES=5% CRF=3.04
1975-1977
%EE = PERCENT EXCEEDENCES ELIMINATED WITH INSPECTION AND MAINTENANCE
90%EE
95%EE
99%EE
100%EE
1980 DRAFT CO GUIDELINE
1981+ DRAFT CO GUIDELINE
CO (GRAMS/MILE)
PRE-RUSH HOUR TEMPERATURE (°F)
30
25
20
15
10
5
0
10
20
30
40
50
60
70
80
90
100

FIGURE 10.

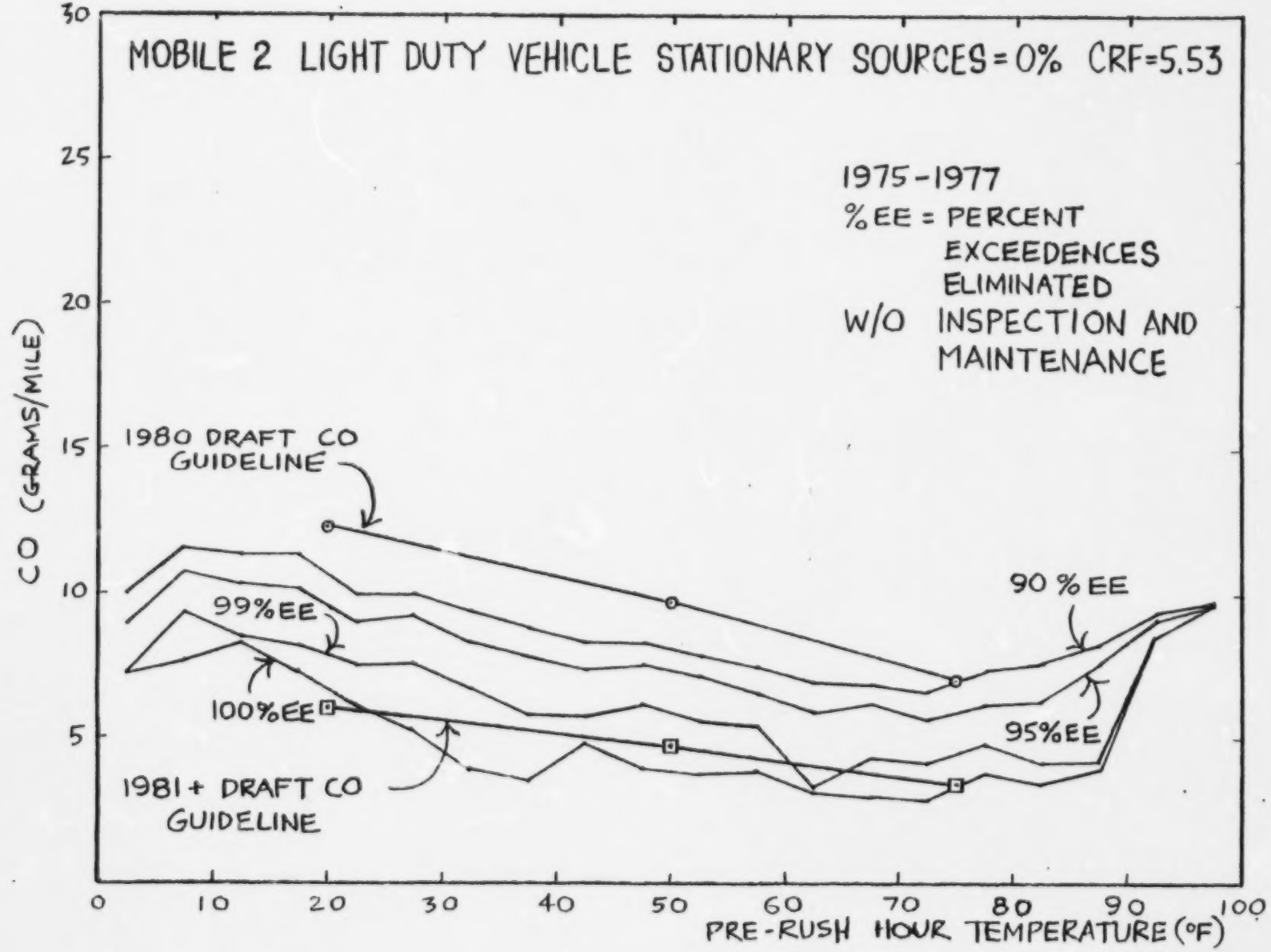

MOBILE 2 LIGHT DUTY VEHICLE STATIONARY SOURCES = 0% CRF=5.53
1975-1977
%EE = PERCENT EXCEEDENCES ELIMINATED W/O INSPECTION AND MAINTENANCE
1980 DRAFT CO GUIDELINE
99%EE
100%EE
1981+ DRAFT CO GUIDELINE
90 % EE
95%EE
CO (GRAMS/MILE)
PRE-RUSH HOUR TEMPERATURE (°F)
30
25
20
15
10
5
0
10
20
30
40
50
60
70
80
90
100

FIGURE 11.

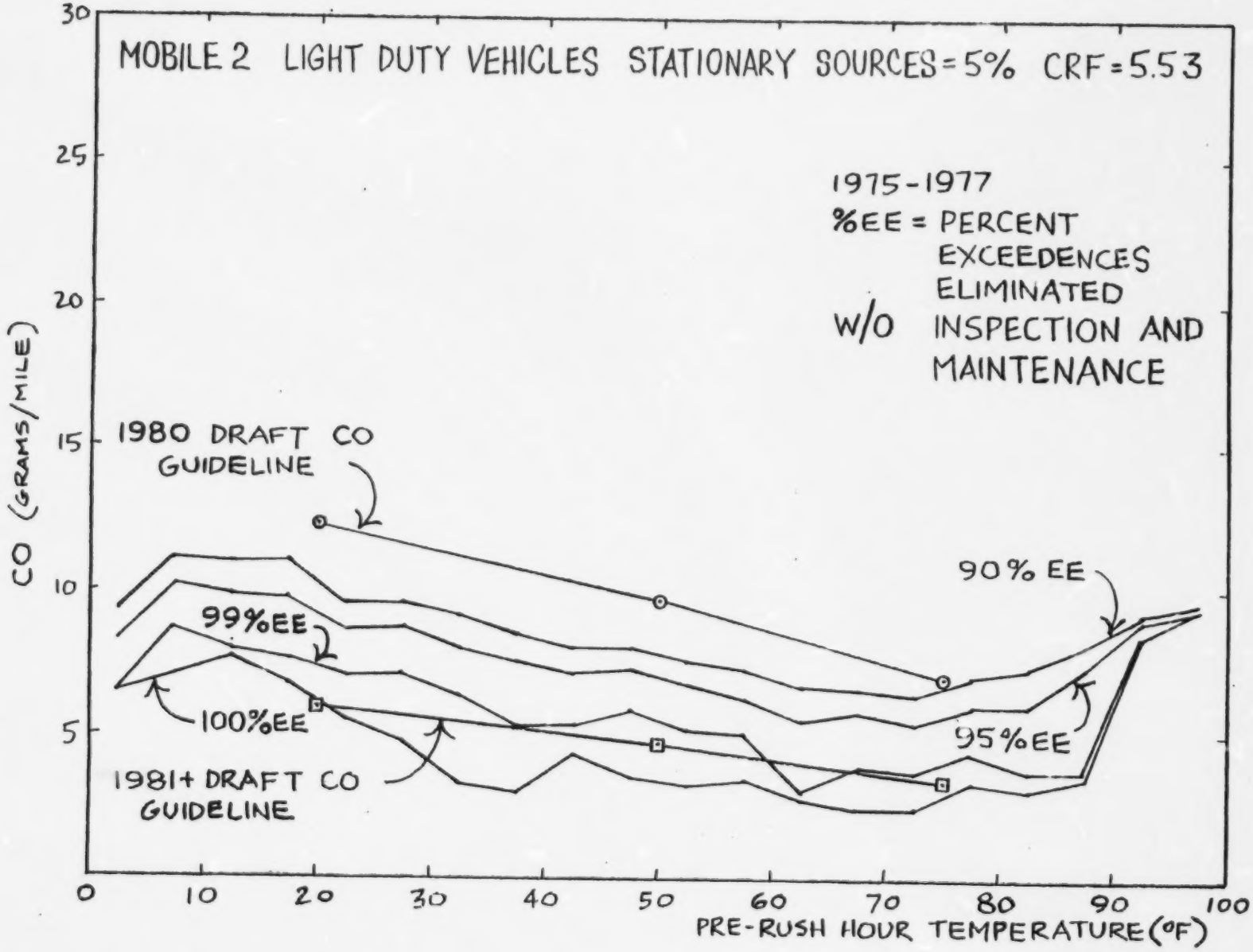

MOBILE 2 LIGHT DUTY VEHICLES STATIONARY SOURCES = 5% CRF = 5.53
1975-1977
%EE = PERCENT EXCEEDENCES ELIMINATED W/O INSPECTION AND MAINTENANCE
1980 DRAFT CO GUIDELINE
90% EE
99%EE
100%EE
95%EE
1981+ DRAFT CO GUIDELINE
CO (GRAMS/MILE)
30
25
20
15
10
5
0
10
20
30
40
50
60
70
80
90
100
PRE-RUSH HOUR TEMPERATURE (°F)

FIGURE 12.

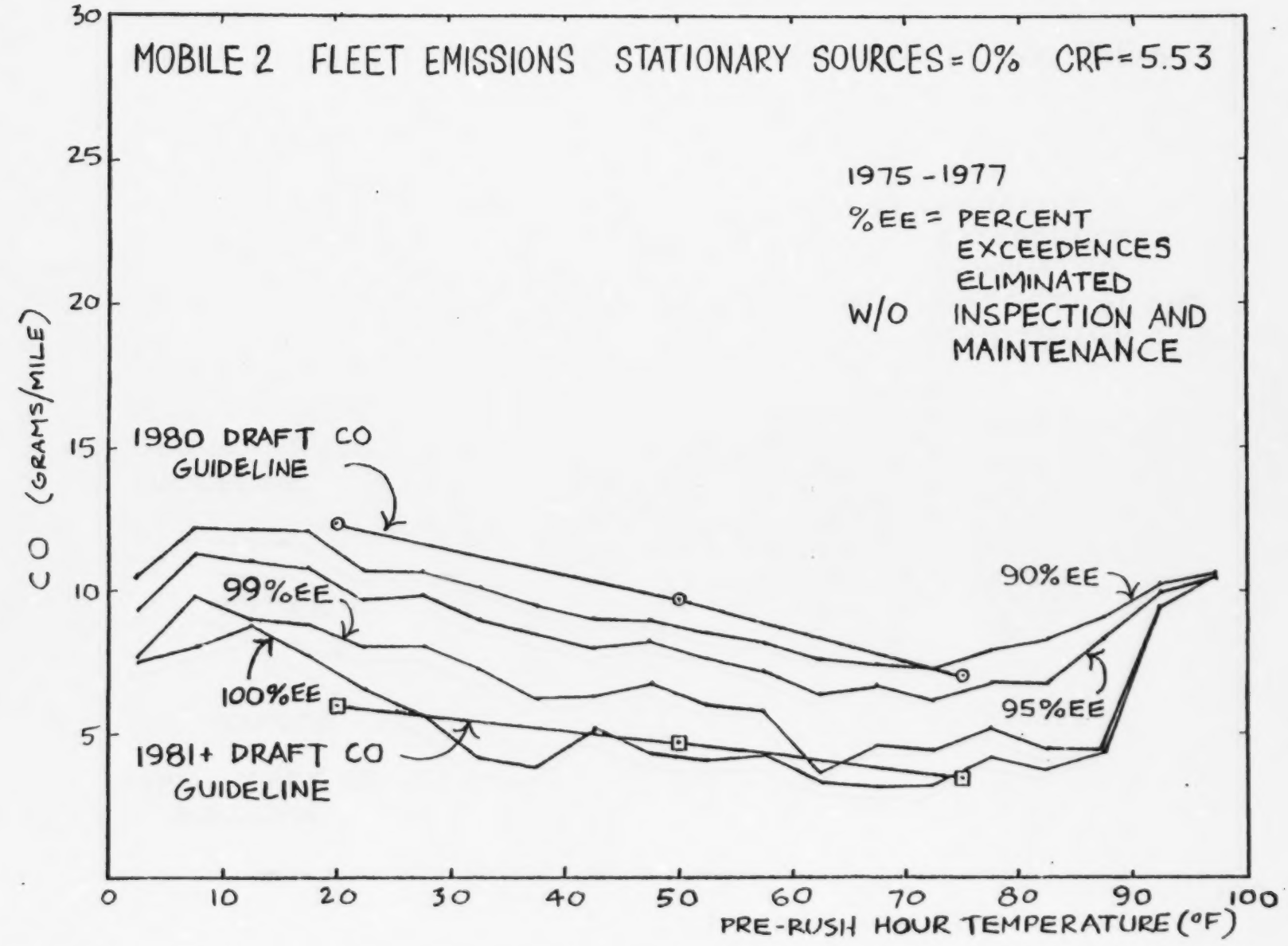
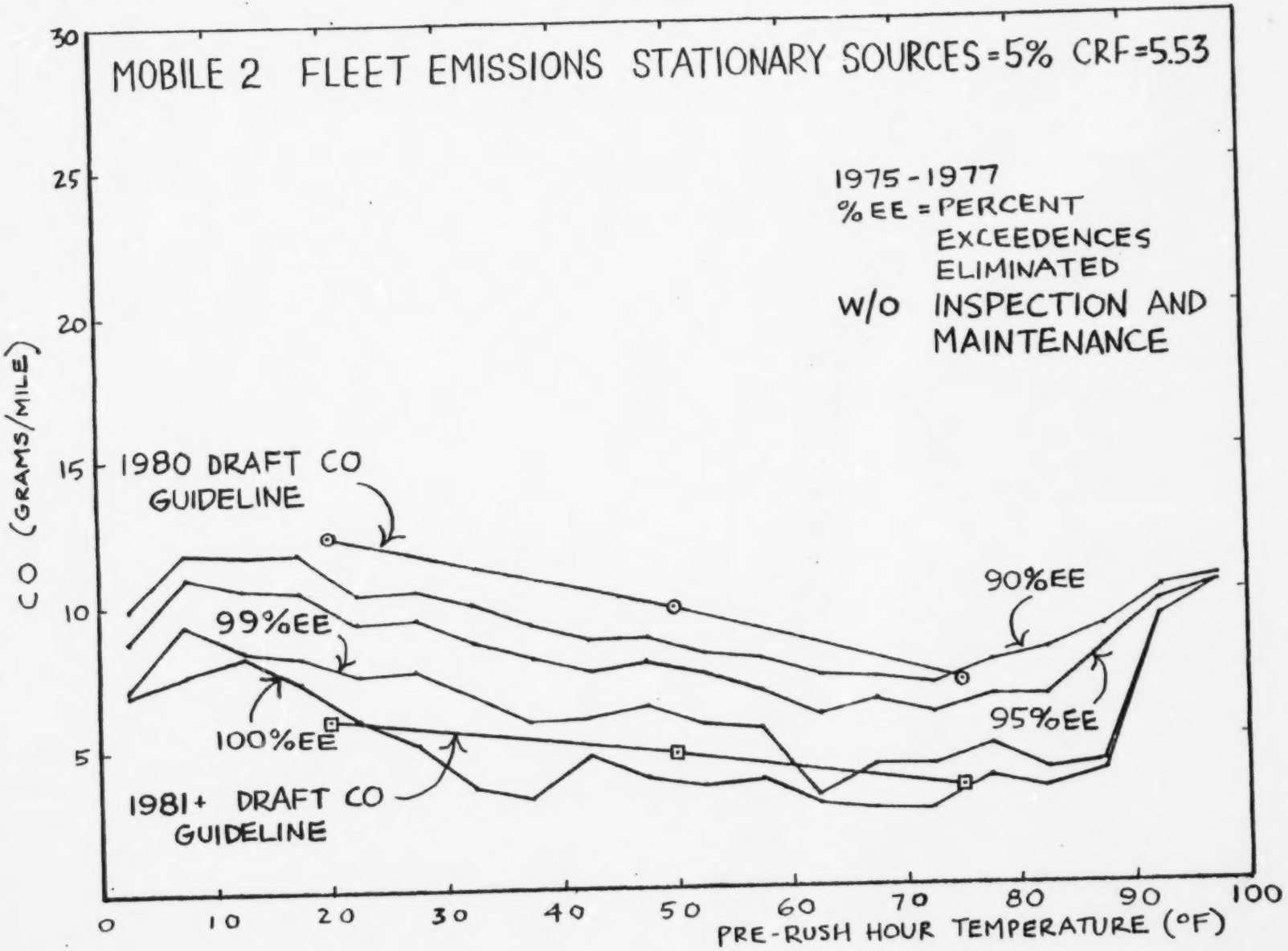

MOBILE 2 FLEET EMISSIONS STATIONARY SOURCES = 0% CRF = 5.53
1975 - 1977
%EE = PERCENT EXCEEDENCES ELIMINATED W/O INSPECTION AND MAINTENANCE
1980 DRAFT CO GUIDELINE
99%EE
100%EE
1981+ DRAFT CO GUIDELINE
90%EE
95%EE
CO (GRAMS/MILE)
PRE-RUSH HOUR TEMPERATURE (°F)
30
25
20
15
10
5
0
10
20
30
40
50
60
70
80
90
100

FIGURE 13.


MOBILE 2 FLEET EMISSIONS STATIONARY SOURCES=5% CRF=5.53
1975-1977
%EE = PERCENT EXCEEDENCES ELIMINATED
W/O INSPECTION AND MAINTENANCE
CO (GRAMS/MILE)
30
25
20
15
10
5
1980 DRAFT CO GUIDELINE
90%EE
99%EE
95%EE
100%EE
1981+ DRAFT CO GUIDELINE
0
10
20
30
40
50
60
70
80
90
100
PRE-RUSH HOUR TEMPERATURE (°F)

EPA Controlled Environment Test Facility Data

The previous analyses both relate CO emission levels needed to eliminate exceedences of the NAAQS to pre-rush hour temperature. The reason for this is that these temperatures more closely represent the ambient temperature that in-use vehicles are soaked at for a number of hours before they are cold started and begin warming up. Rush hour temperature values more commonly represent vehicles operating under warmed up and hot start conditions.

Vehicles tested in the EPA's Controlled Environment Test Facility (CETF) are soaked for 12 to 24 hours at the test temperature before being run on the Federal Test Procedure (FTP), Highway Fuel Economy (HFET) and New York City Cycles (NYCC) (see test sequence, Table 3).

The EPA's emission testing program at different temperatures began in February 1980. To date ten vehicles have completed testing which includes duplicate tests at 20, 60, 75 and 100°F over the FTP, HFET and NYCC cycles. Frequent CETF compressor breakdowns, instrumentation failures, dynamometer problems and competition with other testing programs have delayed the program since then. It was difficult to obtain vehicles which represent the industry sales mix and current emission control technologies. Seven of the ten vehicles were either certification emission data (5) or fuel economy (2) vehicles and the other three were production vehicles, two of which had data from other testing programs with which to correlate. Tests at 75°F in the CETF compared reasonably well to official certification tests for all vehicles run on a Clayton Chassis Dynamometer in a light duty certification test cell.

This program was designed to provide emission test data from vehicles at ambient conditions other than FTP conditions. Temperature tolerances in the test cell were held to ± 5°F during soaks and ± 2°F during vehicle tests. Humidity was controlled at 75 ± 5 gr/lb during vehicle tests at 75 and 100°F and was not controlled during vehicle

Table 3
Test Sequence

1. Refuel to 40% tank capacity.

2. Set-up vehicle on dynamometer for testing.

3. Stabilize ambient conditions in the CETC to within tolerances of desired conditions.

4. Precondition with 1 LA-4 cycle. The blower velocity will be equivalent to a vehicle speed of 20 mph. and the hood will be open.

5. Engine off, 30 minute soak. Airstream will be deflected from the vehicle, hood closed.

6. Rapid cool-down. Blower at 50 mph, undeflected. Hood open.

7. Cool down until oil temperature in oil pan is $\pm$ 2°F of test temperature, then 30 minutes additional cool-down.

8. Emission Test Sequence

   There will be 10 minute soaks between tests. The blower will be at 20 mpg during the sequence and deflected during the 10 minute soaks. The hood will be open during tests and closed during soaks.

   a. Cold Start FTP
   b. HFET
   c. NYC Cycle

9. Refuel to 40% tank capacity.

10. Precondition with 1 LA-4 cycle.

11. 12-24 hour soak. Hood will be closed and airstream deflected. Blower output within $\pm$ 5°F of desired test condition.

12. Repeat step 8 once.

13. Change temperature and humidity to next settings.

14. Refuel to 40% tank capacity.

15. Repeat steps 4-14 for each temperature. Sequence will be 75° - 20° - 60° - 100°F.

soaks. A 10% air conditioning horsepower adjustment was subtracted from 20°F and 60°F tests. No evaporative emissions tests were run. For a complete description of the test sequence refer to Table 3. A complete description of the CETF test vehicles is listed in Table 4. This test program is continuing and the CETF has recently been modified for testing of front wheel drive vehicles.

V. DISCUSSION OF CURRENT DATA

As mentioned, Figures 6 through 13 display the emission levels from Mobile 2 reduced to levels needed to eliminate 90, 95, 99 and 100 percent of the exceedences of the NAAQS with CRFs of 3.04 and 5.53. There is little difference between the values for Mobile 1 and those of Mobile 2. Mobile 2 values are slightly higher, but the differences are mainly at the temperature extremes where there are not much data of high confidence. For simplicity, therefore, CRFs were only applied to Mobile 2 plots. The September 1978 EPA draft CO guidelines at temperatures of 75, 50 and 20°F are shown on each graph as reference lines (see Table A-1 in appendix).

For a CRF of 3.04, the 100% exceedences eliminated curve is above the 1981+ CO guideline in all cases. Assuming there is a correlation between CO emissions at any given temperature to CO emissions at 75°F, this would indicate that adherence to this guideline would be sufficient for eliminating all NAAQS exceedences.

With a CRF of 5.53, the 90% exceedences eliminated curve is below the 1980 CO guideline, and the 1981+ CO guideline (based on a 3.4 grams/mile CO standard at 75°F), approximates a level close to 99% NAAQS exceedences eliminated.

For 90% NAAQS exceedences eliminated, the necessary CO emissions are 1.7 times higher at 20°F than they are at 75°F. This ratio increases up to 2.6 for 100% NAAQS exceedences eliminated. The 1978 CO guideline assumed a ratio of 1.76 in this same temperature interval.

Table 4
EPA CETF TEST FLEET

MY	MFR	MODEL	EMISSION CONTROL SYSTEM	SALES CLASS	AC	Eng. Size (Liters)	No. of Carb. bbls	No. of Cylinders	Trans	Inertia WGT
1979	Ford	T-Bird	EGR, AIR, OC	Calif.	Yes	5.8	2	8	A-3	4500
1980	Nissan	280ZX (FB 223)	FI, EGR, PAIR, OC	49S	Yes	2.8	-	6	A-3	3000
1980	Nissan	280ZX (FB 178)	FI, TWC, CL	Calif.	Yes	2.8	-	6	M-5	3000
1981	GM	Grand Prix	EGR, AIR, OC, TWC, CL	49S	Yes	4.3	2	8	L-3	4000
1980	GM	Cutlass Supreme	EGR, AIR, TWC, CL	49S	Yes	4.3	2	8	A-3	3500
1978	Ford	Pinto	EGR, AIR, TWC, OC, FBC	Calif.	Yes	2.3	2	4	A-3	2750
1980	GM	Regal	RAIR, TWC, CL, FBC	50S	Yes	3.8	2	6	A-3	3500
1981 1/2	Nissan	280ZX (FB 289)	EFI, EGR, TWC, CL, ECCS, TC	49S	Yes	2.8	-	6	A-3	3000
1981	Plymouth	Reliant	EGR, AIR, CL, TWC, OC, FBC	49S	Yes	2.2	2	4	M-4	2750
1980	Toyota	Celica	EGR, TWC, CLEFI	50S	Yes	2.6	-	6	A-40D	3000

The mean FTP results of vehicles tested in EPA's CETF for temperatures of 100, 75, 60 and 20°F are listed in Table 5. The average of the ten vehicles tested so far exhibits CO emissions 4.6 times higher at 20°F than at 75°F on a grams/mile basis. When compared to the certification standard at which these vehicles were calibrated, the average is 2.7 times higher at 20°F than the standard. The average CETF FTP CO vehicle emissions for 75, 60 and 20°F are 4.1, 7.6 and 17.9 grams/mile, respectively. These averages indicate larger CO 20°F/CO 75°F ratios than the levels needed to eliminate 90 to 100% of NAAQS exceedences indicated in the Mobile 2 analysis (Figures 6 to 13).

Table 5
CETF FTP Emissions and Fuel Economy Results (grams/mile)

Test Vehicle	Cert. Veh?	Cert. CO Standard	CO (grams/mile) 100°F	75°F	60°F	20°F	20°F/75°F	20°F/Cert. Standard
Ford Thunderbird	Yes	15	8.72	12.63	24.84	47.34	3.75	3.16
Datsun 280ZX FB 223	Yes	7	2.45	1.86	1.57	4.36	2.34	0.62
Datsun 280ZX FB 178	Yes	7	1.89	2.28	2.96	7.04	3.09	1.01
Pontiac Grand Prix	Yes	3.4	1.29	2.99	15.46	31.32	10.47	9.21
Oldsmobile Cutlass	Yes*	7	2.18	3.17	8.41	21.70	6.85	3.10
Ford Pinto	No	(15)	2.46	4.56	5.95	27.81	6.10	1.85
Buick Regal	No	(7)	8.65	7.92	8.44	16.53	2.09	2.36
Datsun 280ZX Turbo	Yes	3.4	1.46	1.11	1.33	3.81	3.43	1.12
Plymouth Reliant	Yes*	3.4	2.45	2.84	4.09	11.46	4.04	3.37
Toyota Celica Supra	No	(7)	0.95	1.91	2.85	7.87	4.12	1.12
CETF Fleet Average			3.25	4.13	7.59	17.92	4.63	2.69

* Fuel economy vehicle. Not an emission data or durability vehicle.

Table 5 (Cont.)
CETF FTP Emissions and Fuel Economy Results (grams/mile)

Test Vehicle	HC (grams/mile)				NOx (grams/mile)				Fuel Economy (mpg)			
	100°F	75°F	60°F	20°F	100°F	75°F	60°F	20°F	100°F	75°F	60°F	20°F
Ford Thunderbird	0.47	0.76	1.30	3.06	0.73	0.83	1.01	1.10	13.30	13.10	12.55	11.45
Datsun 280ZX FB 223	0.29	0.36	0.31	0.58	1.52	1.52	2.05	2.46	19.57	19.35	19.45	18.50
Datsun 280ZX FB 178	0.27	0.29	0.34	1.00	0.37	0.38	0.36	0.46	20.70	20.30	20.30	18.90
Pontiac Grand Prix	0.30	0.30	1.38	3.69	0.90	0.78	0.96	1.06	18.30	17.75	16.65	15.15
Oldsmobile Cutlass	0.27	0.32	0.61	1.40	0.48	0.54	0.71	1.44	19.65	19.10	18.25	16.85
Ford Pinto	0.32	0.31	0.35	1.30	0.64	0.93	0.67	0.82	24.15	21.05	21.80	20.00
Buick Regal	0.45	0.43	0.38	0.56	0.29	0.42	0.67	2.24	21.05	20.25	20.50	18.25
Datsun 280ZX Turbo	0.26	0.30	0.36	0.73	0.53	0.56	0.68	0.83	19.45	18.85	18.95	16.75
Plymouth Reliant	0.22	0.26	0.50	1.68	0.52	0.51	0.66	0.80	25.33	25.25	25.30	21.90
Toyota Celica Supra	0.12	0.21	0.28	1.25	0.37	0.40	0.54	0.70	22.35	21.73	21.15	19.15

The highest CO emissions at all temperatures were exhibited by the 1979 Ford Thunderbird equipped with EGR, air injection and an oxidation catalyst. The lowest CO emissions at FTP temperatures and below were displayed by the 1981 1/2 Datsun 280ZX equipped with EGR, three-way catalyst, closed loop electronic fuel injection, turbocharger and an electronic engine control system called ECCS. These results seem to agree with the findings of Robert L. Farrell's Temperature Correction Formulae for Adjusting Estimates of Emissions from Automobiles [2 and section II. Summary of Significant Background Studies]. In that report, the system that achieved the lowest bag one FTP CO emissions was a fuel injection, three-way catalyst system.

The vehicle with the highest ratio of CO emissions at 20°F to those at 75°F is the 1981 Pontiac Grand Prix (CO 20°F/CO 75°F = 10.5) with EGR, closed loop, three-way plus oxidation catalyst and air injection. The vehicle with the lowest CO 20°F/CO 75°F ratio (2.1) is the 1980 Buick Regal with a radial aperture tube air injection, closed loop carburetor, and three-way catalyst system.

A number of the background studies used for this report also determined values for cold temperature versus FTP temperature ratios. In Emissions at Off-Ambient Temperatures, the average CO 20°F/CO 75°F FTP ratio for a fleet of 25 1970 model year vehicles is 1.82 [5]. In the follow-up study, Effect of Ambient Temperature and Driving Cycle on Exhaust Emissions, the new fleet performed worse than the 1970 baseline fleet at extreme temperatures when referenced to the 75°F FTP CO levels (CO 25°F/CO 75°F = 3.31) [39].

The mean CETF CO emission results on the HFET and NYCC test cycles are listed in Tables 6 and 7. Two tests were run on each vehicle at all temperatures. All vehicles displayed HFET CO emission levels of less than 1 gram/mile at 75°F and 20°F with the exception of the 1980 Buick Regal and the 1978 Ford Pinto. Eight vehicles were tested on the NYCC. This is a hot start NYCC, however, so the emissions levels are much lower than might be expected if each vehicle were soaked

Table 6
CETF HFET Emissions and Fuel Economy Results

Test Vehicle	CO (grams/mile) 100°F	75°F	60°F	20°F	FE (mpg) 100°F	75°F	60°F	20°F	Cert. CO	Cert. FE
Ford Thunderbird	2.48	0.84	0.09	0.38	20.2	20.6	21.1	20.0	0.04	20.2
Datsun 280ZX FB 223	4.02	0.10	0.02	0.13	25.5	27.3	27.2	27.2	0.00	26.5
Datsun 280ZX FB 178	0.86	0.94	1.00	0.99	33.2	32.0	32.4	32.2	0.99	31.0
Pontiac Grand Prix	0.05	0.05	0.10	0.07	26.6	26.4	26.1	25.3	0.00	26.0
Oldsmobile Cutlass	0.43	0.23	0.19	0.15	25.8	25.8	25.8	25.8	0.12	24.8
Ford Pinto	0.08	0.04	0.04	1.89	31.2	28.0	31.4	29.9	0.05*	-*
Buick Regal	3.74	4.96	1.90	1.19	30.4	29.6	30.9	30.2	-**	-**
Datsun 280ZX FB 289	0.44	0.48	0.46	0.50	23.8	23.5	24.3	23.6	-***	-***
Plymouth Reliant	0.72	0.24	0.34	0.39	35.2	41.5	41.4	40.8	0.13	40.1
Toyota Celica Supra	0.19	0.15	0.09	0.11	29.7	29.4	30.1	29.1	-**	-**

* Southwest Research Institute data
** Production vehicle, no correlative data
*** 1981 1/2 certification vehicle, not certification tested as yet

Table 6 (Cont.)
CETF HFET Emissions and Fuel Economy Results

Test Vehicle	HC (grams/mile) 100°F	75°F	60°F	20°F	NOx (grams/mile) 100°F	75°F	60°F	20°F	Cert. HC	Cert. NOx
Ford Thunderbird	0.11	0.14	0.14	0.16	0.53	0.96	1.16	1.43	0.14	1.30
Datsun 280ZX FB 223	0.05	0.03	0.03	0.04	1.25	1.78	2.07	2.55	0.03	1.88
Datsun 280ZX FB 178	0.07	0.08	0.08	0.07	0.20	0.19	0.20	0.20	0.08	0.21
Pontiac Grand Prix	0.04	0.04	0.11	0.07	0.67	0.64	0.79	1.06	0.03	0.67
Oldsmobile Cutlass	0.05	0.05	0.05	0.06	0.35	0.32	0.37	0.51	0.06	0.33
Ford Pinto	0.06	0.03	0.03	0.04	0.79	0.88	0.73	0.68	0.02	0.68
Buick Regal	0.14	0.14	0.06	0.04	0.14	0.18	0.19	0.29	-**	-**
Datsun 280ZX FB 289	0.05	0.05	0.05	0.05	0.77	0.36	0.28	0.32	-***	-***
Plymouth Reliant	0.04	0.02	0.02	0.03	0.54	0.30	0.34	0.43	0.02	0.29
Toyota Celica Supra	0.01	0.01	0.01	0.01	0.11	0.13	0.17	0.19	-**	-**

* Southwest Research Institute data
** Production vehicle, no correlative data
*** 1981 1/2 certification vehicle, not certification tested as yet

Reproduced from best available copy.

Table 7
CETF NYCC Emissions and Fuel Economy Results*

	CO (grams/mile)				HC (grams/mile)			
	100°F	75°F	60°F	20°F	100°F	75°F	60°F	20°F
Datsun 280ZX FB 178	5.35	1.64	2.68	1.93	0.45	0.31	0.48	0.28
Pontiac Grand Prix	3.27	3.14	0.74	0.30	0.37	0.36	0.98	0.24
Oldsmobile Cutlass	-	-	3.78	2.60	-	-	0.40	0.39
Ford Pinto	3.65	1.28	1.54	9.56	0.38	0.28	0.32	0.63
Buick Regal	20.18	-	18.20	16.88	1.25	-	0.92	0.71
Datsun 280ZX Turbo	4.97	0.99	0.85	1.14	0.43	0.30	0.29	0.27
Plymouth Reliant	11.01	8.32	6.25	4.76	0.68	0.74	0.60	0.50
Toyota Celica Supra	5.30	2.43	2.29	2.55	0.28	0.10	0.11	0.09

	NOx (grams/mile)				FE (mpg)			
	100°F	75°F	60°F	20°F	100°F	75°F	60°F	20°F
Datsun 280ZX FB 178	0.79	0.84	0.79	1.16	11.50	11.65	11.45	11.45
Pontiac Grand Prix	1.07	1.24	1.46	1.28	10.50	10.55	10.40	10.80
Oldsmobile Cutlass	-	-	0.96	1.14	-	-	10.45	10.60
Ford Pinto	0.81	0.93	1.12	1.36	13.60	12.30	12.40	11.25
Buick Regal	0.48	-	0.66	1.10	11.90	-	11.90	11.60
Datsun 280ZX Turbo	1.05	1.05	1.49	1.37	12.20	12.25	12.40	11.67
Plymouth Reliant	0.41	0.46	0.52	1.85	13.30	13.25	13.20	8.90
Toyota Celica Supra	0.61	0.35	0.41	0.55	13.05	13.17	13.30	12.65

*This NYCC is a hot start test. Vehicles were soaked at the test temperature only 10 minutes after being run on a HFET at the same soak temperature. (See Table 3 - Test Sequence.)

several hours at the test temperature instead of 10 minute soaks following a HFET.

The CETF FTP CO bag results are listed on a grams/mile basis in Table 8 and on a grams/bag basis in Table 9. Table 8 shows that bag one cold start emissions are the major CO contributors with 81% of total FTP CO emissions at 75°F and 92% at 20°F.

Emissions from bag one of the FTP at 20°F increased an average of 5.3 times over the 75°F grams/mile levels. In the CO Hot Spot Study, it was found that with soak temperatures of 10°F to 25°F, CO exhaust emissions from bag one of the FTP increased by factors ranging from 3 to 7 over identical tests following 68°F to 80°F soaks for 1976 model year vehicles [15]. On a grams/bag basis (Table 9), the bag one portion again rose from 80% to 92% of the total CO emissions from 75°F to 20°F as the average bag one contribution climbed from about 50 to 275 grams.

The relationships between FTP HC, CO and NOx emissions and fuel economy versus temperature for all vehicles tested in the CETF are shown in Figures 14-21. Emissions data from a data base complied by Vector Research, Inc. in a report entitled Draft Data Base for the Development of Improved Temperature Correction Factors for Emissions, and CETF CO emissions data were examined to see if a linear relationship exists between CO emissions at various temperatures and CO emissions at 75°F. Vehicle CO emissions were plotted for 0, 20, 40, 60, 80 and 100°F versus CO emissions at 75°F. Additionally, CETF vehicle CO emissions were plotted for 20, 60 and 100°F versus CO emissions at 75°F (see Figures 22-24). Table 10 lists the statistical analysis of these plots. A correlation coefficient (R) of 1 indicates a linear relationship exists, whereas values close to zero indicate no relationship exists between the two variables.

The results are for the most part, inconclusive. However, it can be said that in model years preceding 1972 there is very little

Table 8

CETF FTP CO Bag Results (grams/mile)

1979 Ford T-Bird	75°F	PCT	20°F	PCT
Bag 1	49.39	86%	203.44	93%
Bag 2	0.75	1%	6.27	3%
Bag 3	7.61	13%	7.96	4%
1980 Datsun 280ZX (FB 223)				
Bag 1	7.63	87%	20.76	99%
Bag 2	0.04	1%	0.00	0%
Bag 3	1.08	12%	0.31	1%
1980 Datsun 280ZX (FB 178)				
Bag 1	7.34	79%	29.11	91%
Bag 2	0.94	10%	1.29	4%
Bag 3	1.03	11%	1.48	5%
1981 Pontiac Grand Prix				
Bag 1	9.96	76%	150.19	99%
Bag 2	0.25	2%	0.16	0%
Bag 3	2.93	22%	1.00	1%
1980 Oldsmobile Cutlass				
Bag 1	13.69	93%	102.85	99%
Bag 2	0.30	2%	0.55	0%
Bag 3	0.75	5%	0.65	1%
1978 Ford Pinto				
Bag 1	20.36	94%	93.09	78%
Bag 2	0.15	1%	5.73	5%
Bag 3	1.10	5%	20.53	17%
1980 Buick Regal				
Bag 1	16.31	58%	60.17	85%
Bag 2	5.12	18%	5.27	8%
Bag 3	6.93	24%	4.98	7%

Table 8 (Cont'd)

CETF FTP CO Bag Results (grams/mile)

1981 1/2 Datsun 280ZX (FB 289)	75°F	PCT	20°F	PCT
Bag 1	3.16	73%	15.65	91%
Bag 2	0.60	14%	0.59	3%
Bag 3	0.55	13%	0.98	6%
1981 Plymouth Reliant				
Bag 1	8.59	72%	51.16	94%
Bag 2	0.64	5%	0.49	1%
Bag 3	2.70	23%	2.57	5%
1980 Toyota Celica Supra				
Bag 1	8.11	88%	36.29	97%
Bag 2	0.55	6%	0.48	1%
Bag 3	0.53	6%	0.55	2%

CETF Fleet Average	75°F	PCT	20°F	PCT
Bag 1	14.45	81%	76.27	92%
Bag 2	0.93	5%	2.08	3%
Bag 3	2.52	14%	4.10	5%

Table 9

CETF FTP CO Bag Results (grams/bag)

1979 Ford T-Bird	75°F	PCT	20°F	PCT
Bag 1	177.29	85%	730.36	93%
Bag 2	2.95	2%	24.71	3%
Bag 3	27.33	13%	28.57	4%
1980 Datsun 280ZX (FB 223)				
Bag 1	26.94	87%	74.90	99%
Bag 2	0.05	0%	0.00	0%
Bag 3	3.89	13%	1.10	1%
1980 Datsun 280ZX (FB 178)				
Bag 1	26.39	78%	104.69	91%
Bag 2	3.67	11%	5.10	4%
Bag 3	3.69	11%	5.32	5%
1981 Pontiac Gran Prix				
Bag 1	35.68	76%	538.59	99%
Bag 2	0.98	2%	0.62	0%
Bag 3	10.51	22%	3.60	1%
1980 Oldsmobile Cutlass				
Bag 1	49.23	93%	367.19	99%
Bag 2	1.18	2%	2.14	0%
Bag 3	2.72	5%	2.32	1%
1978 Ford Pinto				
Bag 1	73.08	94%	333.93	78%
Bag 2	0.59	1%	22.29	5%
Bag 3	3.98	5%	73.81	17%
1980 Buick Regal				
Bag 1	58.29	57%	217.13	85%
Bag 2	19.89	19%	20.59	8%
Bag 3	24.79	24%	17.89	7%

Table 9 (Cont'd)

CETF FTP CO Bag Results (grams/bag)

1981 1/2 Datsun 280ZX (FB 289)	75°F	PCT	20°F	PCT
Bag 1	11.34	72%	56.26	90%
Bag 2	2.33	15%	2.30	4%
Bag 3	1.97	13%	3.53	6%
1981 Plymouth Reliant				
Bag 1	30.54	71%	181.88	94%
Bag 2	2.46	6%	1.89	1%
Bag 3	9.70	23%	9.00	5%
1980 Toyota Celica Supra				
Bag 1	26.63	88%	130.16	97%
Bag 2	1.97	7%	1.87	1%
Bag 3	1.56	5%	1.98	2%

CETF Fleet Average	75°F	PCT	20°F	PCT
Bag 1	51.54	80%	273.51	92%
Bag 2	3.61	6%	8.15	3%
Bag 3	9.01	14%	14.71	5%

CETF DATA SUMMARY
FTP HC VS TEMP

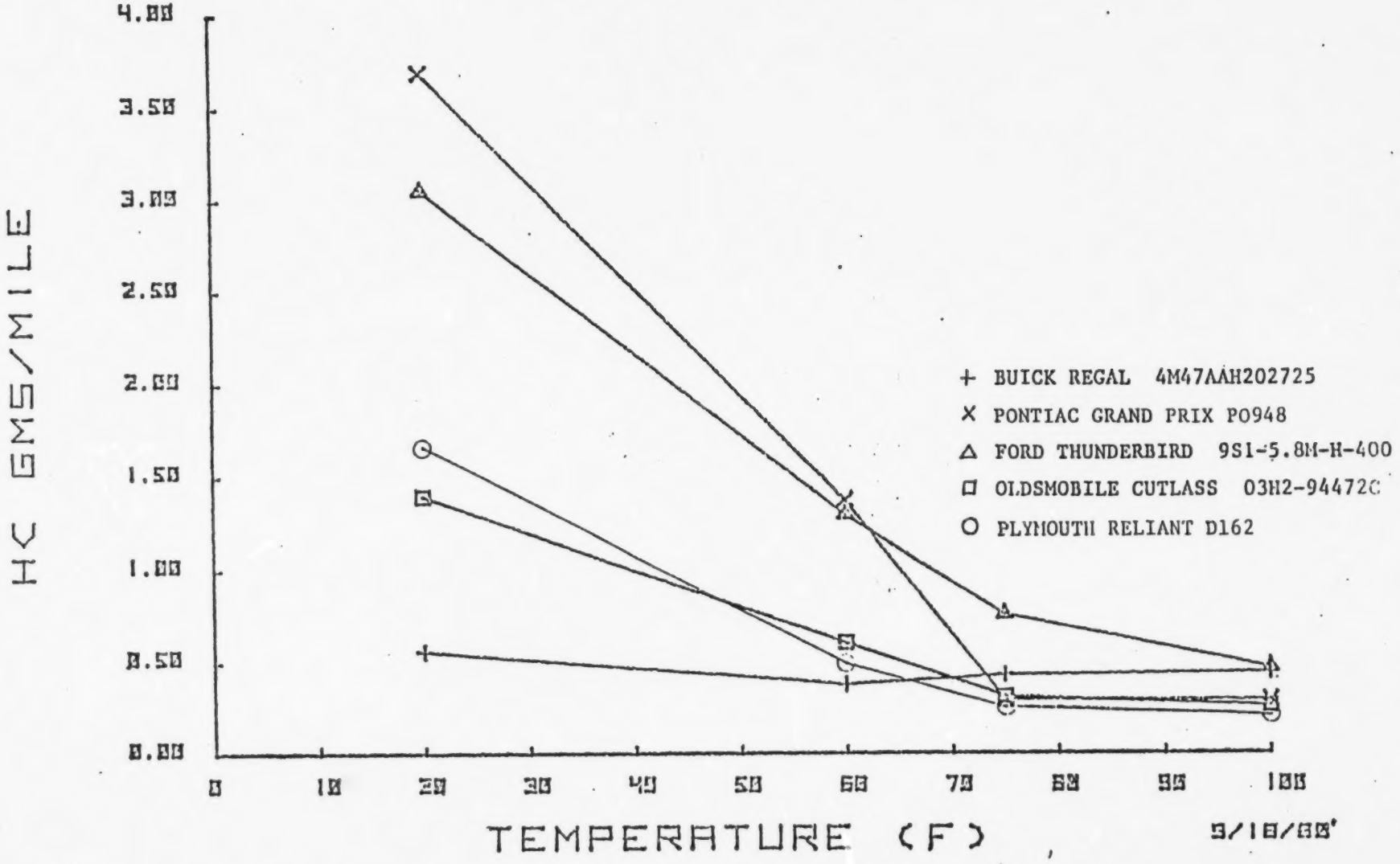
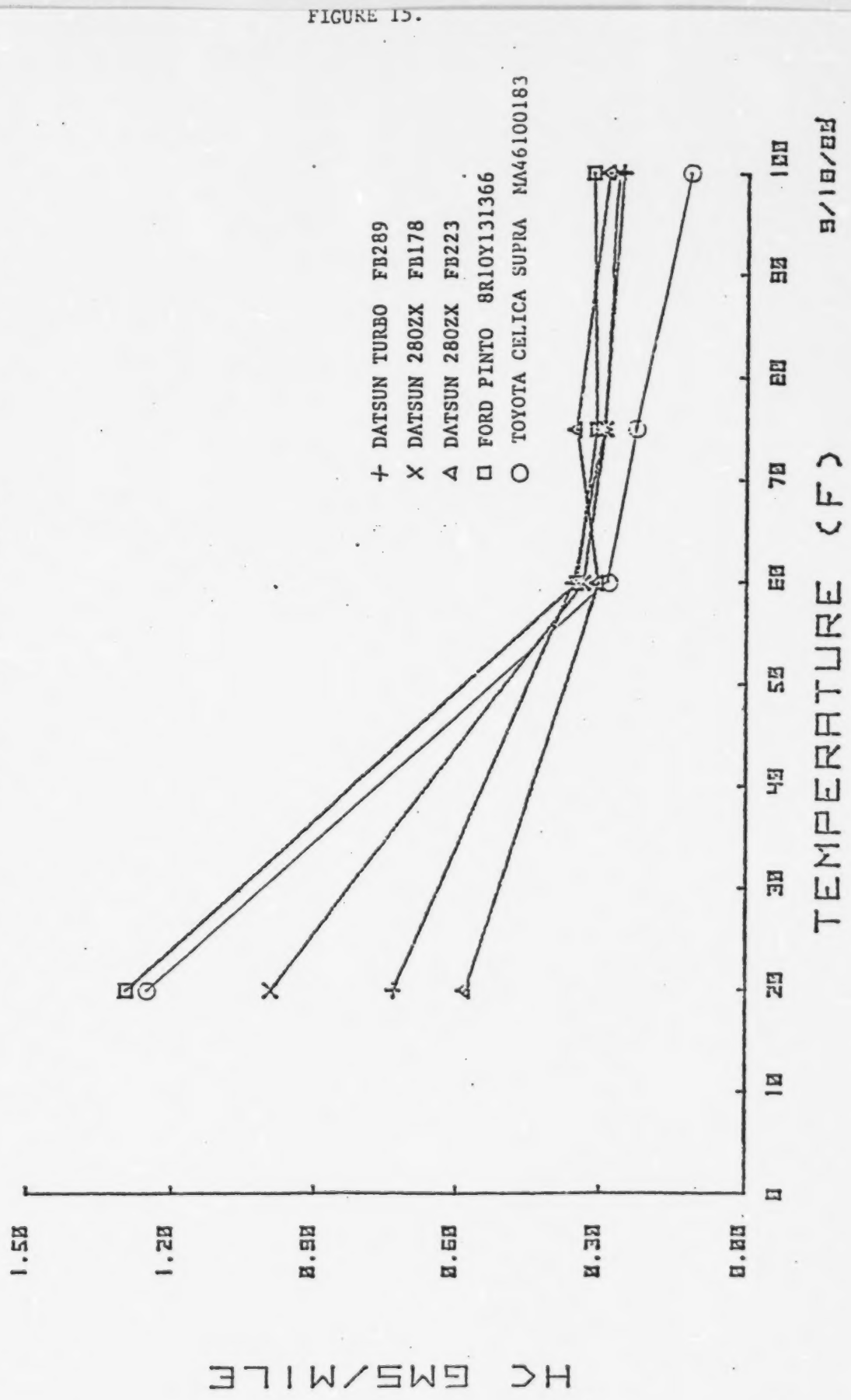


FIGURE 15.


CETF DATA SUMMARY
FTP HC VS TEMP
+ DATSUN TURBO FB289
X DATSUN 280ZX FB178
△ DATSUN 280ZX FB223
□ FORD PINTO 8R10Y131366
○ TOYOTA CELICA SUPRA MA46100183
HC GMS/MILE
1.50
1.20
0.90
0.60
0.30
0.00
0
10
20
30
40
50
60
70
80
90
100
TEMPERATURE (F)
9/10/84

CETF DATA SUMMARY
FTP CO VS TEMP

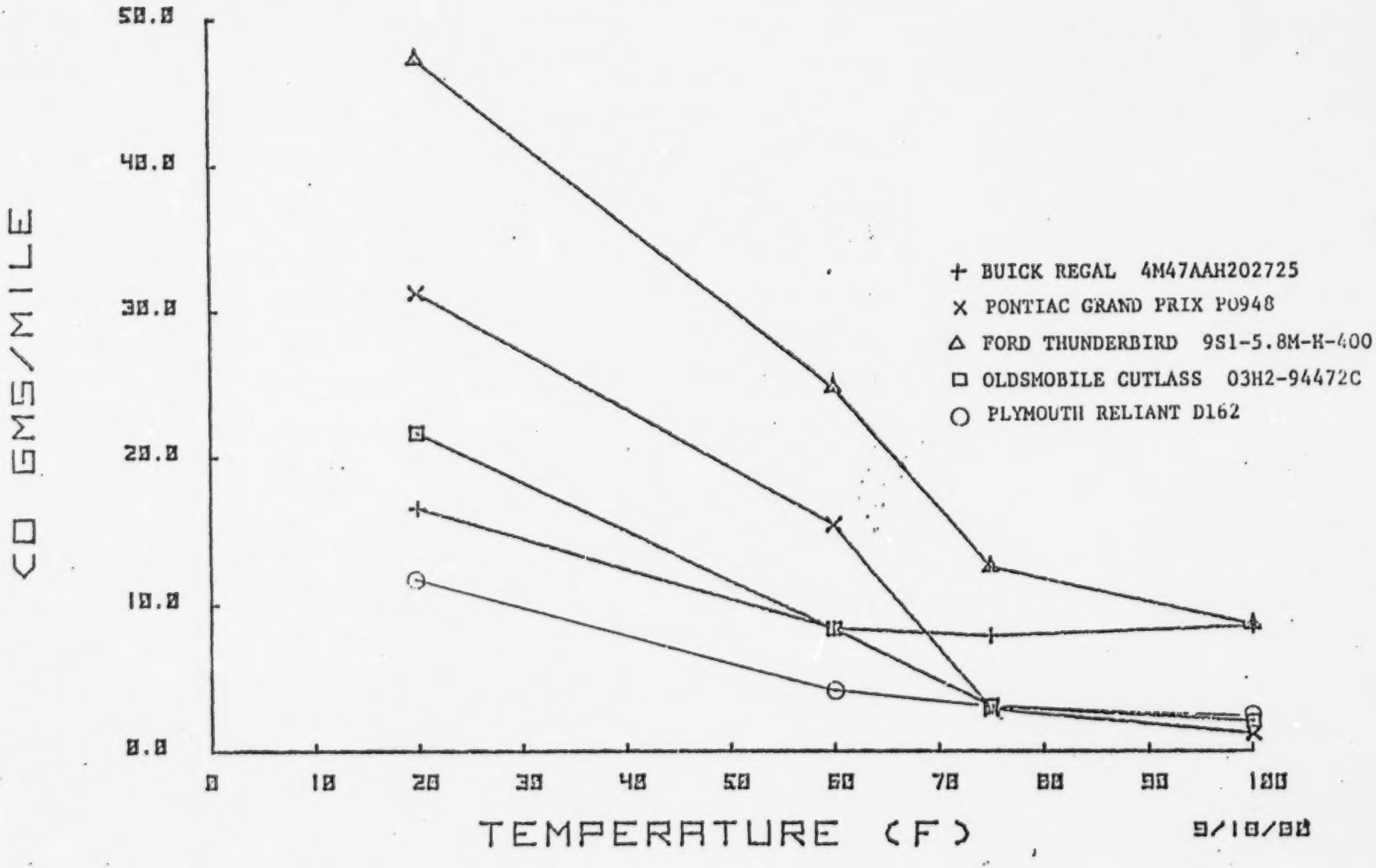
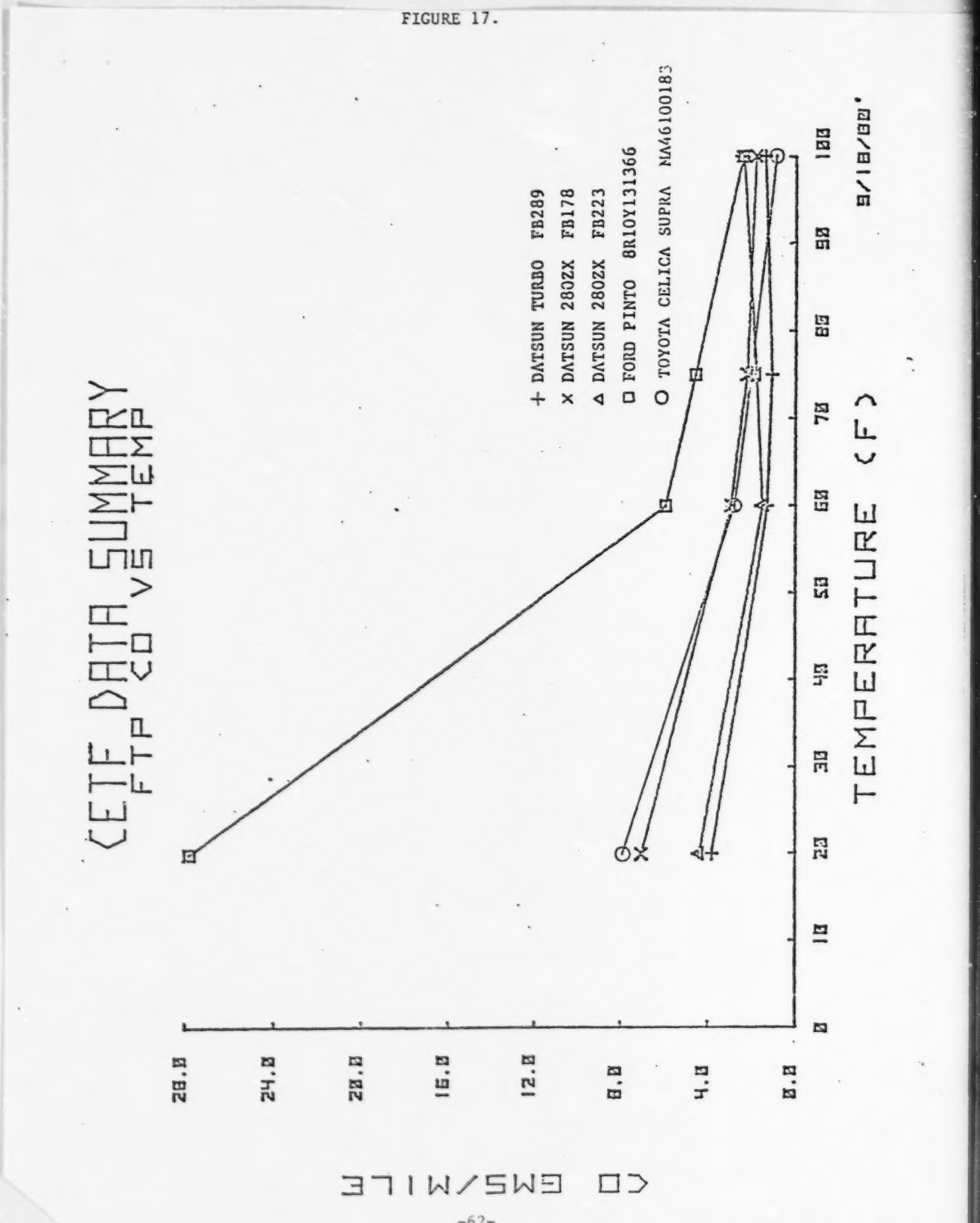
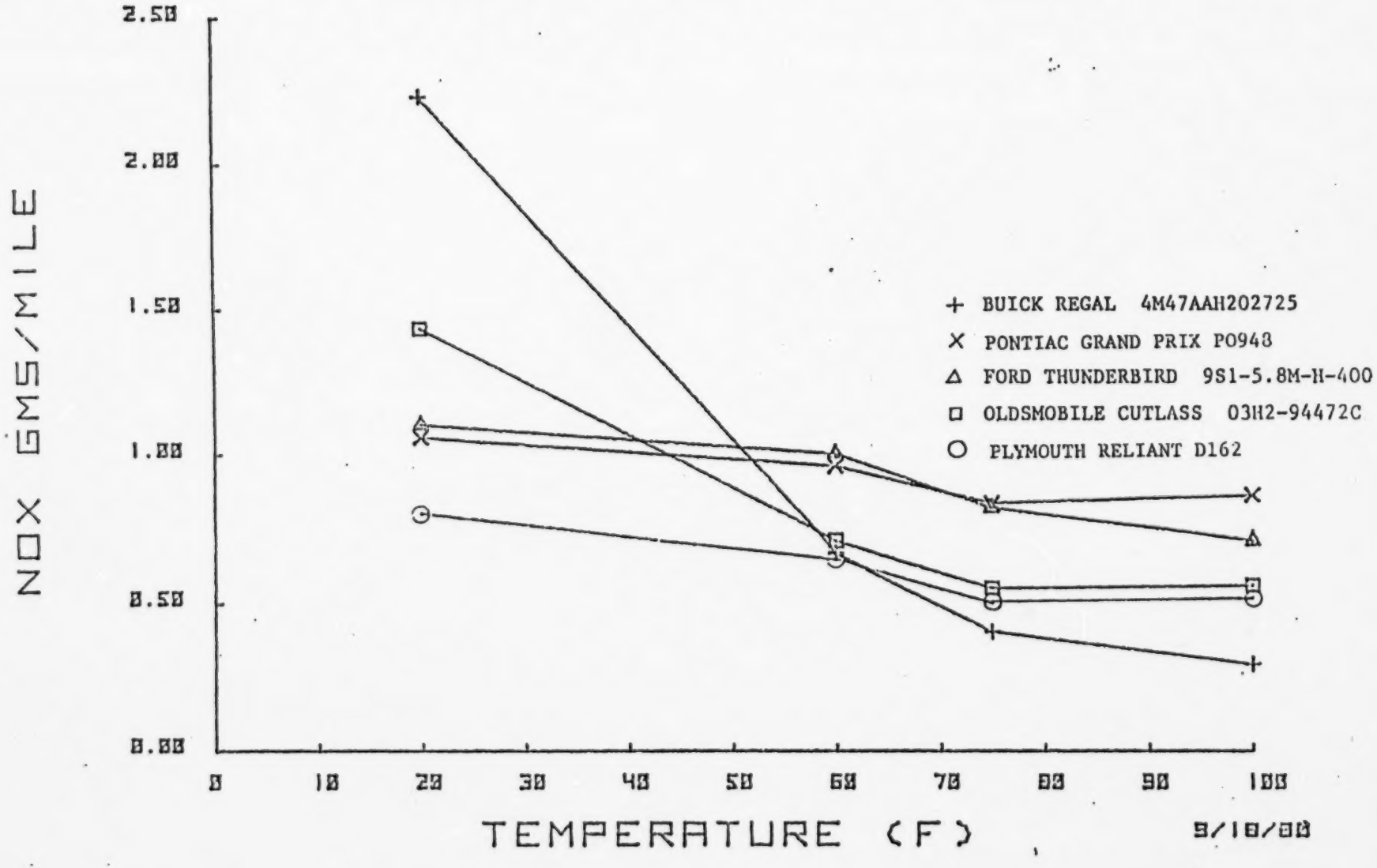


FIGURE 17.


CETF DATA SUMMARY
FTP CO VS TEMP
+ DATSUN TURBO FB289
× DATSUN 280ZX FB178
△ DATSUN 280ZX FB223
□ FORD PINTO 8R10Y131366
○ TOYOTA CELICA SUPRA MA46100183
8/18/80
TEMPERATURE (F)
CO GMS/MILE
0.0
4.0
8.0
12.0
16.0
20.0
24.0
28.0
0
10
20
30
40
50
60
70
80
90
100

CETF DATA SUMMARY
FTP NOX VS TEMP



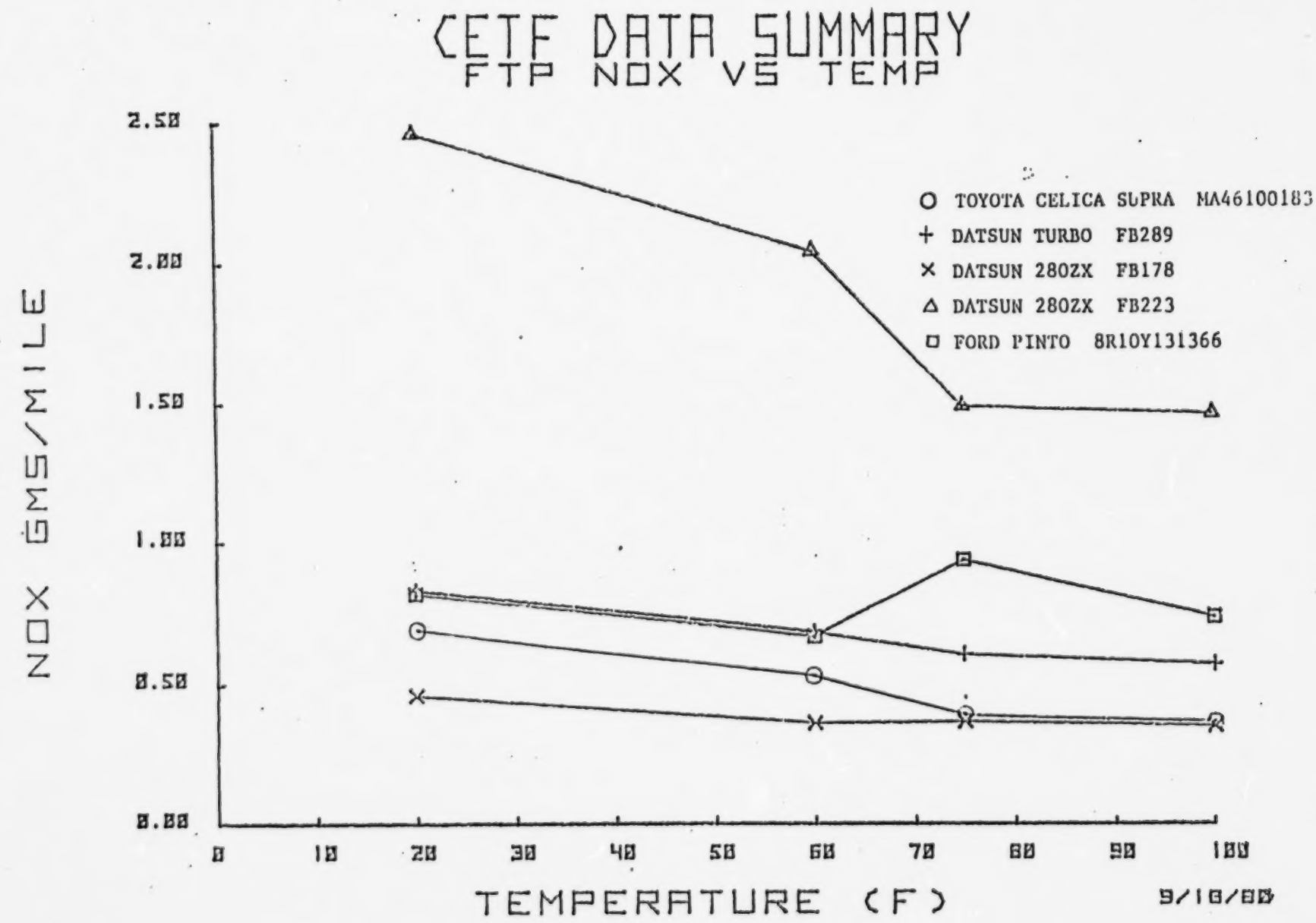

CETF DATA SUMMARY
FTP NOX VS TEMP
NOX GMS/MILE
2.50
2.00
1.50
1.00
0.50
0.00
0
10
20
30
40
50
60
70
80
90
100
TEMPERATURE (F)
9/10/80
TOYOTA CELICA SUPRA MA46100183
DATSUN TURBO FB289
DATSUN 280ZX FB178
DATSUN 280ZX FB223
FORD PINTO 8R10Y131366

FIGURE 19.

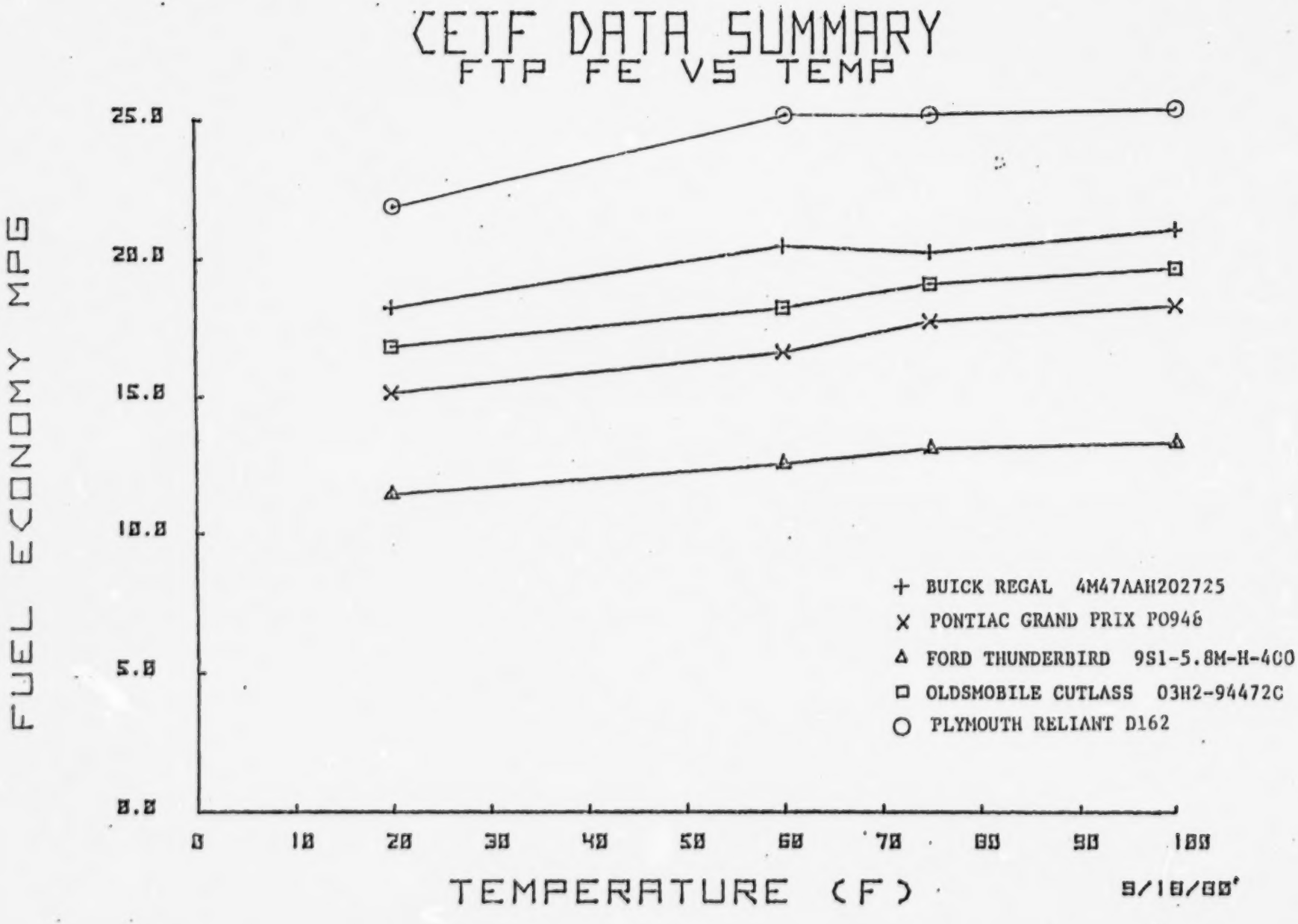

CETF DATA SUMMARY
FTP FE VS TEMP
FUEL ECONOMY MPG
25.0
20.0
15.0
10.0
5.0
0.0
0
10
20
30
40
50
60
70
80
90
100
TEMPERATURE (F)
9/10/80
+ BUICK REGAL 4M47AAH202725
X PONTIAC GRAND PRIX P0946
Δ FORD THUNDERBIRD 9S1-5.8M-H-4CO
□ OLDSMOBILE CUTLASS 03H2-94472C
○ PLYMOUTH RELIANT D162

FIGURE 20.

CETF DATA SUMMARY
FTP FE VS TEMP

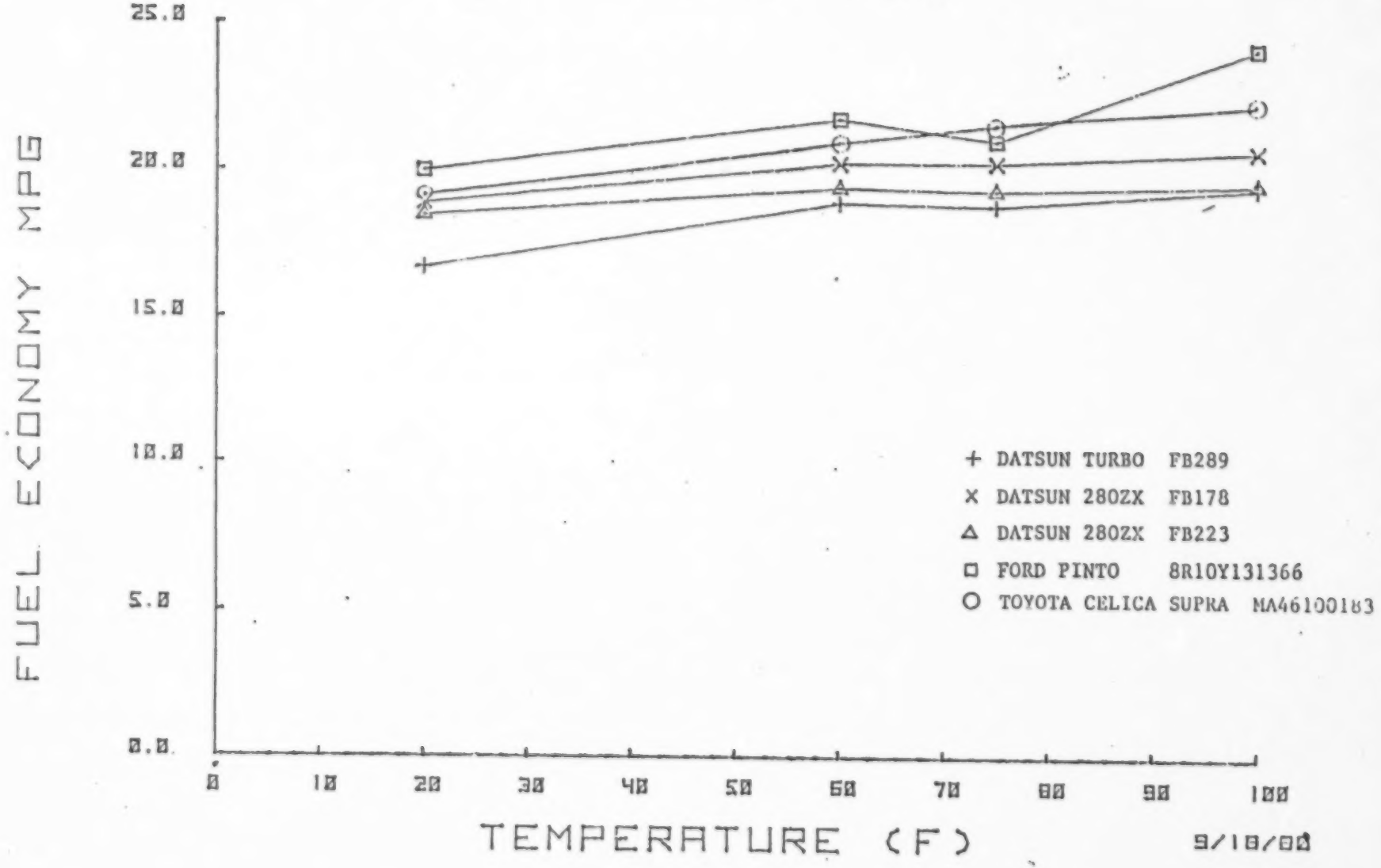


FIGURE 22.

COMPARISON OF CETF CO EMISSIONS AT 20°F RELATIVE TO CO EMISSIONS AT 75°F ON THE FTP

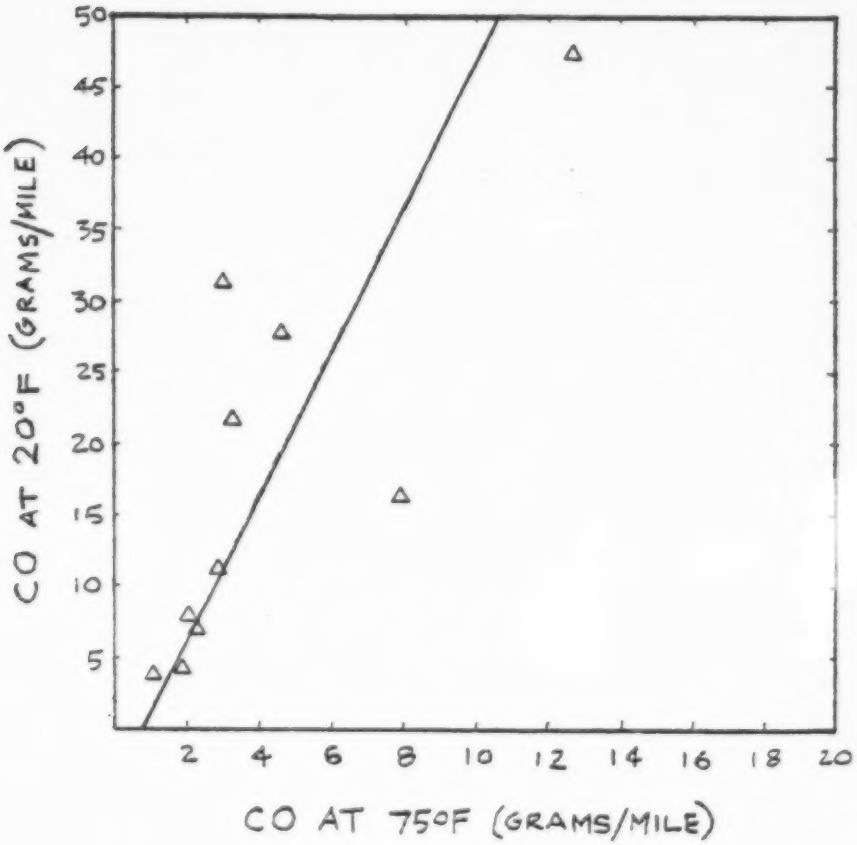


FIGURE 23.

COMPARISON OF CETF CO EMISSIONS AT 60°F RELATIVE TO CO EMISSIONS AT 75°F ON THE FTP

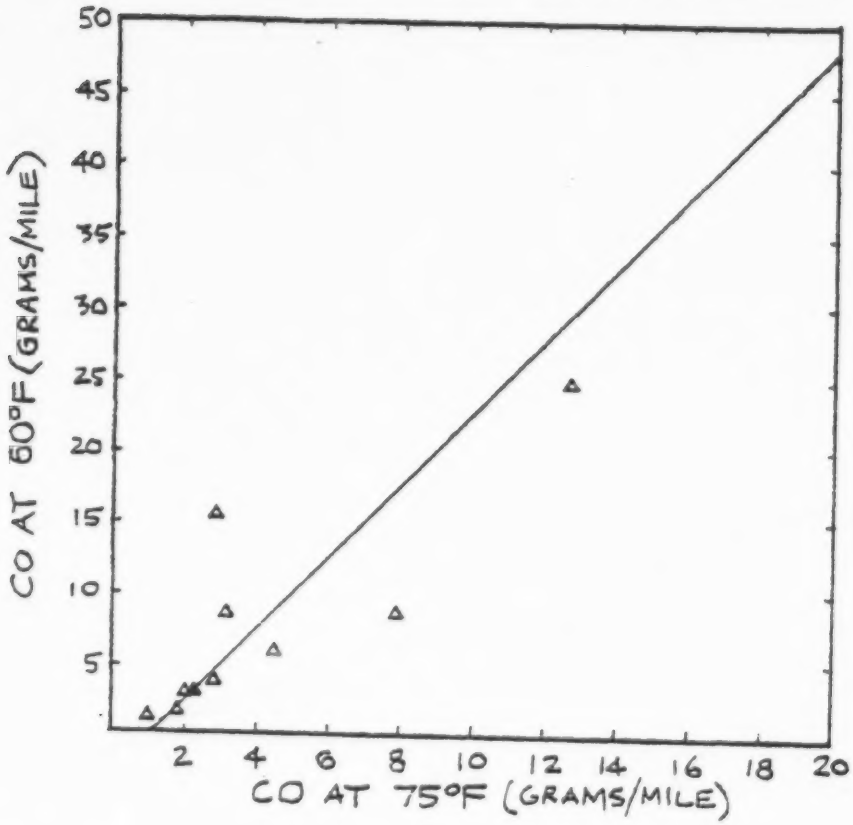


FIGURE 24.

COMPARISON OF CETF CO EMISSIONS AT 100°F RELATIVE TO CO EMISSIONS AT 75°F ON THE FTP

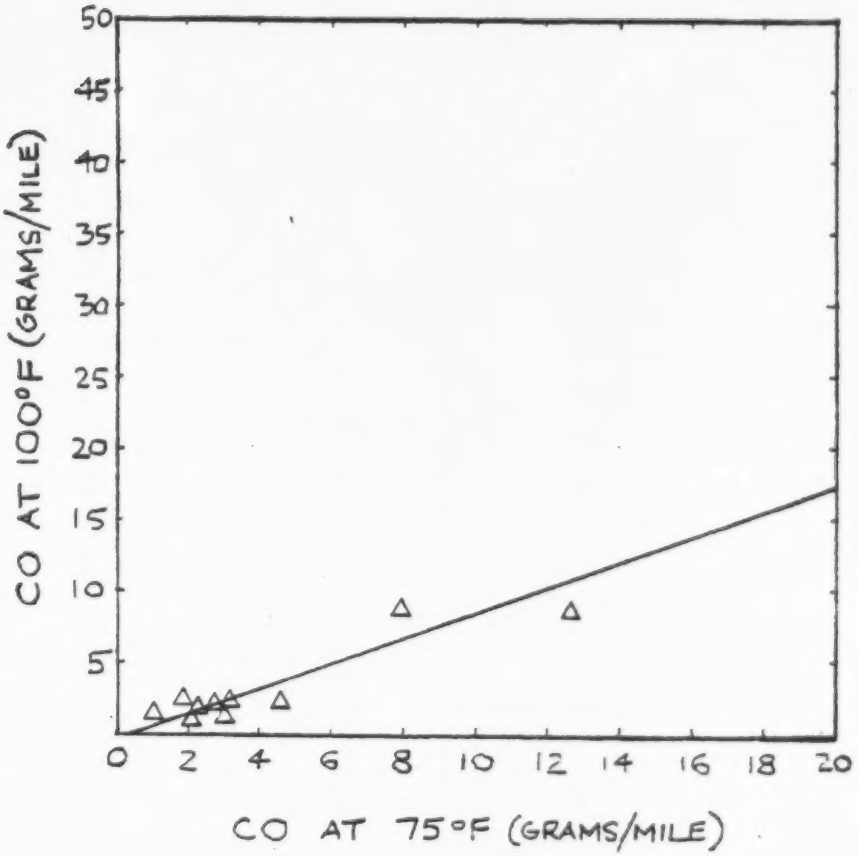


Table 10
CORRELATION OF VRI DATA VEHICLE* CO EMISSIONS AT VARIOUS TEMPERATURES RELATIVE TO CO EMISSIONS AT 75°F

Model Year Correlation Group	Temperature(°F) vs. 75°F	No of Vehicles	Coefficient(R)	R^2	Significance
PRE 1968	20	3	0.39	0.15	0.74
1968-1969	20	4	0.81	0.65	0.19
1970-1971	20	7	0.02	0.00	0.06
1972-1974	20	11	0.83	0.69	0.00
"	40	3	0.99	0.99	0.07
"	100	2	-	-	-
1975-1979	0	9	0.11	0.01	0.77
"	20	27	0.89	0.79	0.00
"	40	18	0.96	0.91	0.00
"	60	8	0.48	0.23	0.23
"	80	5	0.13	0.02	0.83
"	100	8	0.87	0.75	0.02
1980-1981	20	10	0.78	0.61	
"	60	10	0.83	0.68	
"	100	10	0.92	0.85	

* Vehicles from several test programs were merged in a data base by Vector Research, Inc. (VRI). Reference 42 contains descriptions of the test programs and vehicles.

relationship between CO emissions at non-FTP temperatures and CO emissions at 75°F. From 1972 on, a linear relationship exists in most cases, especially the cases with the most data. Intuitively, one might expect a better relationship at temperatures closer to 75°F, with a decreasing relationship as one compares temperatures closer to 0°F. Such is not the case with 1975-1979 vehicles by examination of the correlation coefficients at 80°F and 0°F. CETF CO emissions data (1980-81 model year group) show fairly high correlations at all temperatures relative to 75°F.

This analysis is useful in evaluating whether controlling CO emissions at different levels at FTP temperatures affects CO emissions levels at non-FTP temperatures. Unfortunately, the amount of data available to date is insufficient to make definative conclusions.

VI. REFERENCES

1) A Review of Carbon Monoxide Emissions from Motor Vehicles During Cold Temperature Operation, Alaska Department of Environmental Conservation, (November, 1978), revised March, 1979.

2) Temperature Correction Formulae for Adjusting Estimates of Emissions from Automobiles, by Vector Research, Inc., EPA Contract No. A-2098-NASX, Robert L. Farrell, Volumes I & II, September, 1979.

3) EPA memo from Karl Hellman to Robert Garbe entitled Analysis for Improved Emissions vs. Temperature Influence, April 3, 1979.

4) Effect of Ambient Temperature on Vehicle Emissions and Performance Factors, by Gulf Research and Development Co., R. S. Spindt, R. E. Dizak, R. M. Stewart, W. A. P. Meyer, (Appendix A, B, C), Report No. EPA-460/3-79-006A, September, 1979.

5) Emissions at Off-Ambient Temperatures, W. F. Marshall, B. H. Eccleston, DOE, Bartlesville, Energy Technology Center, OK, SAE Paper No. 800512, presented at the Congress and Exposition, Detroit, MI, February 25-29, 1980.

6) Methodologies for Projecting the Relative Air Quality Impacts of Emission Control Strategies, James H. Wilson, Jr., U.S. EPA, Durham, N.C., presented at the 71st Annual Meeting of the Air Pollution Control Association (APCA), Houston, Texas, June 25-30, 1978.

7) The Exhaust Emission and Fuel Consumption Characteristics of an Engine During Warmup-A Vehicle Study, Donald J. Pozniak, General Motors Research Labs, SAE Paper No. 800396, presented at the Congress and Exposition, Detroit, MI, February 25-29, 1980.

8) Microprocessor Control Brings About Better Fuel Economy With Good Driveability, Kenji Ikeura, Akio Hosaka, and Founeomi Yano, Nissan Motor Co., SAE Paper No. 800056, presented at the Congress and Exposition, Detroit, MI, February 25-29, 1980.

9) Study to Determine Accuracy of the 10% Load Factor for Air Conditioning, Engineering Evaluation Section, Engineering Branch, Vehicle Emission Control Division, California Air Resources Board, June, 1978.

10) An Upper Limit Analysis of Carbon Monoxide Monitoring in the United States, R. L. Ferrari & K. H. Jones, Ph.D., Council on Environmental Quality (CEQ), APCA Journal, June 15, 1979.

11) Projections of Carbon Monoxide Exposure Risk to Stable Angina Pectoris Patients in Four Cities, K. Jones, T. Chapman, R. Ferrari, & N. Buskwick, CEQ, January, 1979.

12) A Continuous Stress Function Relating Ambient Carbon Monoxide Exposure and Excess Angina Pectoris Attacks, K. H. Jones, CEQ, John Knelson, EPA, Research Triangle Park (RTP), N.C., 1979.

13) Effect of Cold Weather on Motor Vehicle Emissions and Fuel Consumption II, Nicolas Ostrouchov, Mobile Sources Division, Environment Canada, SAE Paper No. 790229, presented at the Congress and Exposition, Detroit, MI, February 26 - March 2, 1979.

14) The Development of Improved Temperature Correction Factors for Emissions, Purchase Order by Jay Wallace, EPA, Ann Arbor, MI, April 13, 1979.

15) CO Hot Spot Preliminary Investigation, Gregg Service, Testing and Evaluations Branch (TAEB), Emission Control Technology Division (ECTD), Office of Mobile Source Air Pollution Control (OMSAPC), EPA, December, 1977.

16) Ambient Temperature Effects on Exhaust Emissions of Closed-loop Emission Control System Vehicles, T.M. Fisher, Director, Automotive Emission Control, GM, July 19, 1978.

17) Emissions Under Non-FTP Temperature and Speed Conditions, Characterization and Applications Branch (CAB), ECTD, EPA, Lois Platte, July, 1978.

18) Effects of Low Ambient Temperature on the Exhaust Emissions and Fuel Economy of 84 Automobiles in Chicago, TAEB, ECTD, EPA, Wayne Heinmiller, October, 1978.

19) Control Techniques for Carbon Monoxide Emissions, Emission Standards and Engineering Division (ESED), Office of Air Quality Planning and Standards (OAQPS), RTP, EPA-450/3-79-006, June, 1979.

20) Mobile Source Emission Factors (For Low Altitude Areas Only) EPA, Office of Transportation and Land Use Policy (OT&LUP), EPA-400/9-78-006, March, 1978.

21) Sensitivity of Exhaust Emissions from Late Model Year Passenger Cars Under Non-FTP Conditions, Gary T. Jones, CAB, ECTD, EPA, CAB-9/Non-FTP-2, September, 1978.

22) Rationale and Discussion of Potential Highway Cycle Emissions Guidelines, Gary T. Jones, CAB, ECTD, EPA, CAB-9/Non-FTP-2, September, 1978.

23) Ambient Pollutant Violations Versus Average Temperature, Lois Platte, CAB, ECTD, EPA, August 4, 1978.

24) Ambient Temperature Effects on Exhaust Emissions of Closed Loop Emission Control System Vehicles (Additional Data), Gerald J. Barnes, Director, Automotive Emission Control, GM, December 20, 1978.

25) Transmittal of Draft 202(a)(4) Advisory Circular, Charles L. Gray, Director, ECTD, EPA, September 12, 1978.

26) Transmittal of GM 1980-X Emission Summary, Craig Harvey, ECTD, EPA, September 6, 1978.

27) GM Micro-Computer Engine Control System, R.A. Grimm, R.J. Bremer, S.P. Stonestreet, GM Emission Control Project Center, SAE Paper No. 800053, presented at the Congress and Exposition, Detroit, MI, February 25-29, 1980.

28) Letter from M.E. Rivers of Environment Canada to Ron Bright of Ford regarding HC, CO Step Increase at Low Temperature, December 7, 1979.

29) Memo from Mark Wolcott, TEB, EPA to Charles Gray, Director, ECTD, EPA entitled The Relationship Between Ambient Carbon Monoxide and Temperature, April 17, 1980.

30) Memo from F.P. Hutchins, TAEB, EPA to Charles Gray, Director, ECTD, EPA entitled Preliminary Results of the Temperature Effects Investigation at Gulf Research, EPA, October 3, 1978.

31) National Emission Inventory Interim Report Number 1, Mark Wolcott, TEB, EPA, February 26, 1980.

32) Test Results of 4 Vehicles Regulated and Unregulated Emissions Under Non-FTP Conditions, Jim Braddock, Mobile Source Emissions Research Branch (MSERB), Office of Research and Development (ORD), EPA, May 2, 1980.

33) Memo from F.P. Hutchins, TAEB, EPA to Charles Gray, Director, ECTD, EPA, entitled Michael P. Walsh's Request for Comments on Environment Canada Letter to Ford (HC & CO Step Increase at Low Temperature), January 18, 1980.

34) Vehicle Emissions and Fuel Consumption in Canadian Winter Temperatures, N. Ostrouchov, Environment Canada, presented at the 73rd Annual Meeting of the Air Pollution Control Association, June 22-27, 1980.

35) Methodologies for Projecting the Relative Air Quality Impacts of Emission Control Strategies, James H. Wilson, Jr., U.S. EPA, presented at the 71st Annual Meeting of the Air Pollution Control Association, June 25-30, 1978.

36) Compilation of Air Pollution Emission Factors; Highway Mobile Sources, OMSAPC, EPA, March 1981.

37) Urban-Center CO Air Quality Projections, T.V. Chang, J.M. Norbeck and B. Weinstock, Ford Motor Co., Journal of the Air Pollution Control Association, Vol. 30, No. 9, September, 1980.

38) Draft Advisory Circular on non-FTP Conditions, Compliance with the Requirements of Section 202(a)(4) and 206(a)(3) of the Clean Air Act for 1980 and Later Model Years, September 19, 1978.

39) Effect of Ambient Temperature and Driving Cycle on Exhaust Emissions, W.F. Marshall, U.S. DOE, Bartlesville, Oklahoma, EPA 460/3-80-012, June, 1980.

40) Evolution of Federal Light-Duty Mass Emission Regulations, Thomas A. Huls, Environmental Protection Agency, SAE Paper No. 730554, May 14-18, 1973.

41) Environmental Quality 1979; The Tenth Annual Report to the President of the Council on Environmental Quality, December 1979.

42) Draft Data Base for the Development of Improved Temperature Correction Factors for Emissions, Vector Research, Inc., VIR-EPA-5 FR79-1, July 27, 1979.

43) Draft Air Quality Criteria for Carbon Monoxide, Environmental Criteria and Assessment Office, U.S. Environmental Protection Agency, Research Triangle Park, NC, April 1979.

VII. APPENDIX

Table A-1

1978 CO Guidelines from Draft Advisory Circular on non-FTP Conditions [38]

Ratio of Value Over FTP at Specified Temperature to Value of Emission Standard at 75°

Cycle	Temperature (°F)[1] 20	50	75
NYCC[2]			2.30
FTP	1.76	1.38	1.00 (1.05[4])
HFET[3]			0.42

1980 Model Year LDVs CO Guidelines (gpm)

Cycle	Temperature (°F)[1] 20	50	75
NYCC[2]			16.1
FTP	12.3	9.7	7.0 (7.4[4])
HFET[3]			2.9

1981 and Later Model Year LDVs CO Guidelines (gpm)

Cycle	Temperature (°F)[1] 20	50	75
NYCC[2]			7.8
FTP	6.0	4.7	3.4(3.6[4])
HFET[3]			1.4

[1]Temperature tolerance for a valid test should be ± 5°F.

[2]NYCC is started from a hot idle.

[3]The HFET is the EPA highway fuel economy test.

[4]This denotes guideline with air-conditioning. These guidelines for air-conditioning for HC, CO, and NOx should be used for any engine family where air-conditioning is expected to be sold on over 33% of the number of vehicles produced. The 75° air-conditioning factor refers to the ratio of a:b where "a" is the emission level on a hot start 1972 FTP at 75° with vehicle air-conditioning on (as described below) without the 10% road load air-conditioning simulation, and "b" is the emission level on the 1975 FTP at 75° without vehicle air-conditioning, but with the 10% road load air-conditioning simulation. The 110° air-conditioning factor refers to the ratio of c:d where "c" is the emission level on the 1975 FTP at 110° with vehicle air-conditioning on (as described below) without the 10% road load air-conditioning simulation, and "d" is the emission level on the 1975 FTP at 75° without vehicle air-conditioning and without the 10% road load air-conditioning simulation. The air-conditioning tests should be conducted with the air-conditioning control set at the coolest setting, the interior air recirculated, the fan set to the highest speed, and the refrigerant charged as recommended by the manufacturer.

References: Hutchins, F.P., 3 internal EPA memos: "Effects of Air Conditioning Operation on Older Cars' Emissions (67-72-MY)", 5/23/78, "Modification of Air Conditioning Factors", 6/1/78, "Air Conditioning Effects Factors in the Draft Advisory Circular", 6/16/78. These are based on two studies: "A Study of Emissions from 1967-1974 Light Duty Vehicles in Denver, Houston, and Detroit", (EPA-460/3-74-015), and "Ambient Temperature and Vehicle Emissions", (EPA-460/3-74-028).

FIGURE A-1

MOBILE 1

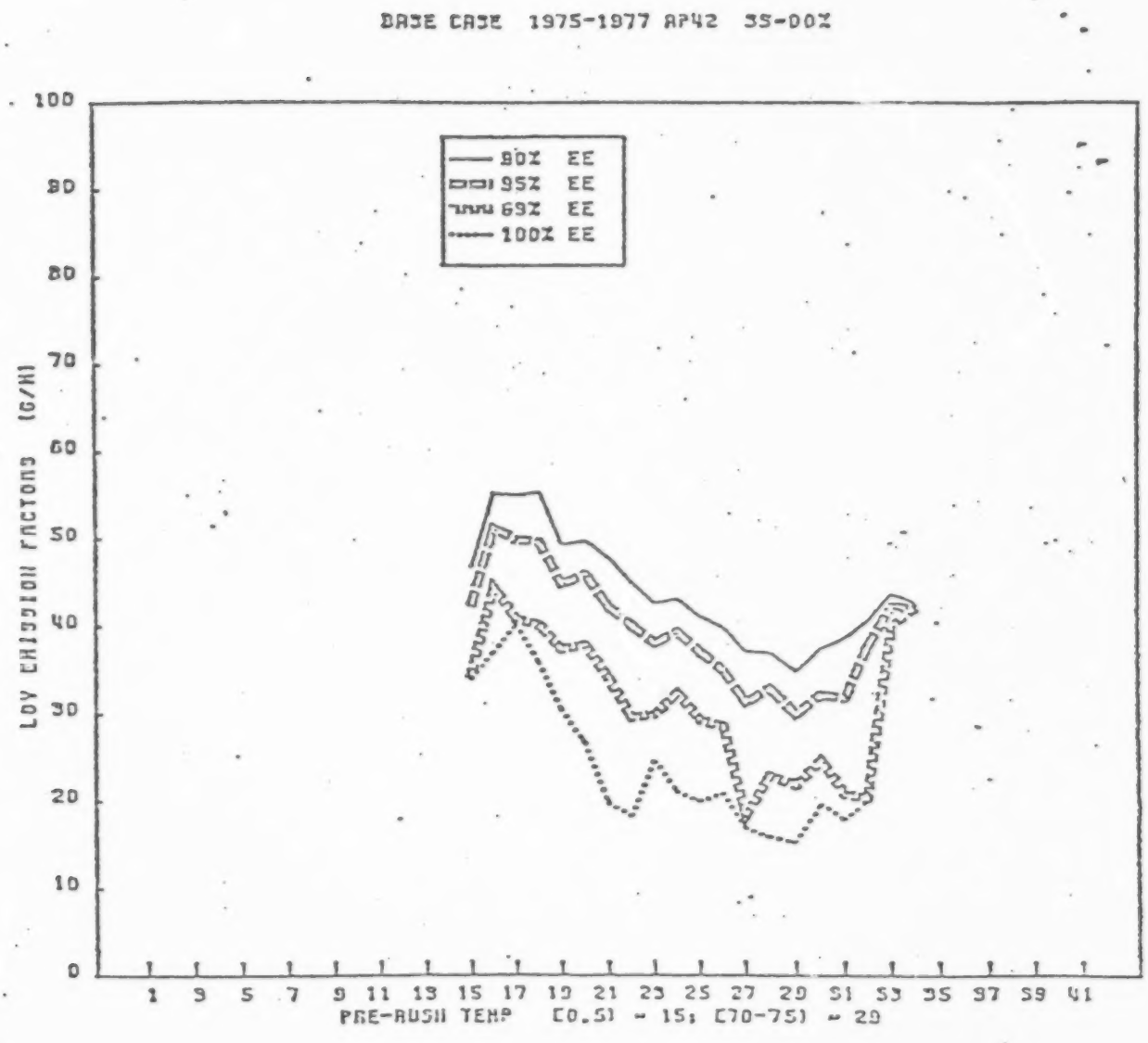


FIGURE A-2

MOBILE 1

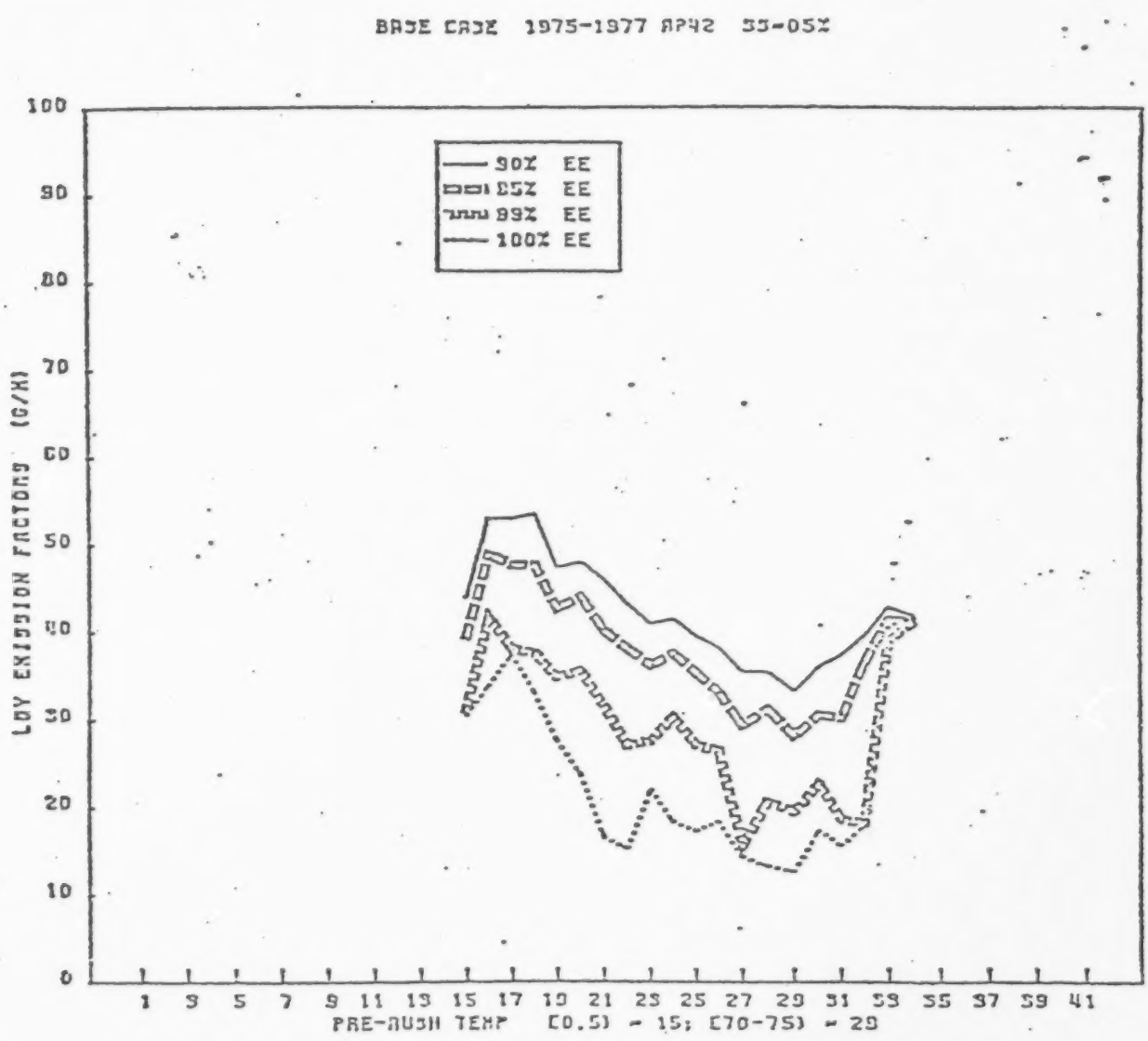


FIGURE A-3

MOBILE 1

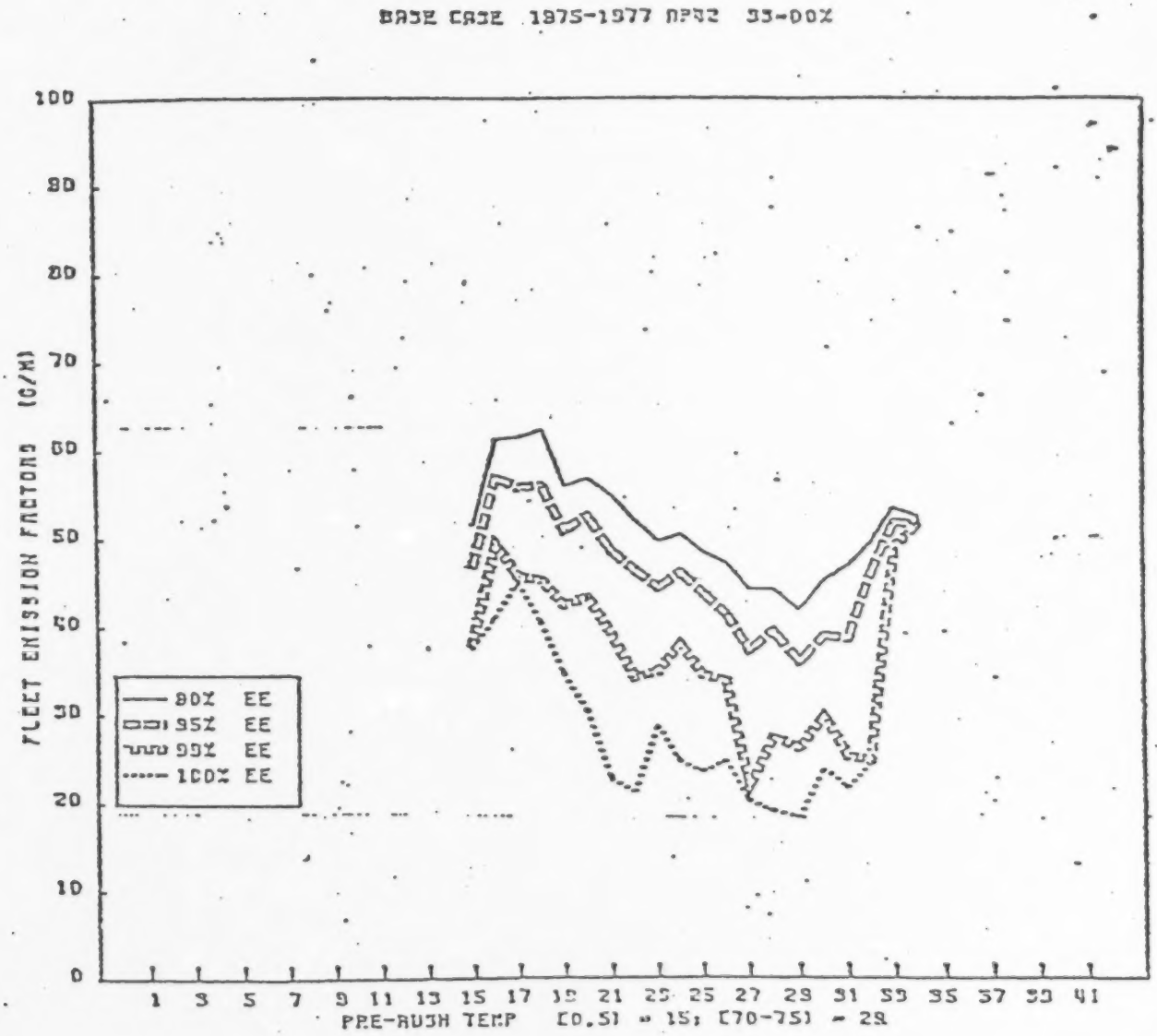


FIGURE A-4

MOBILE 1

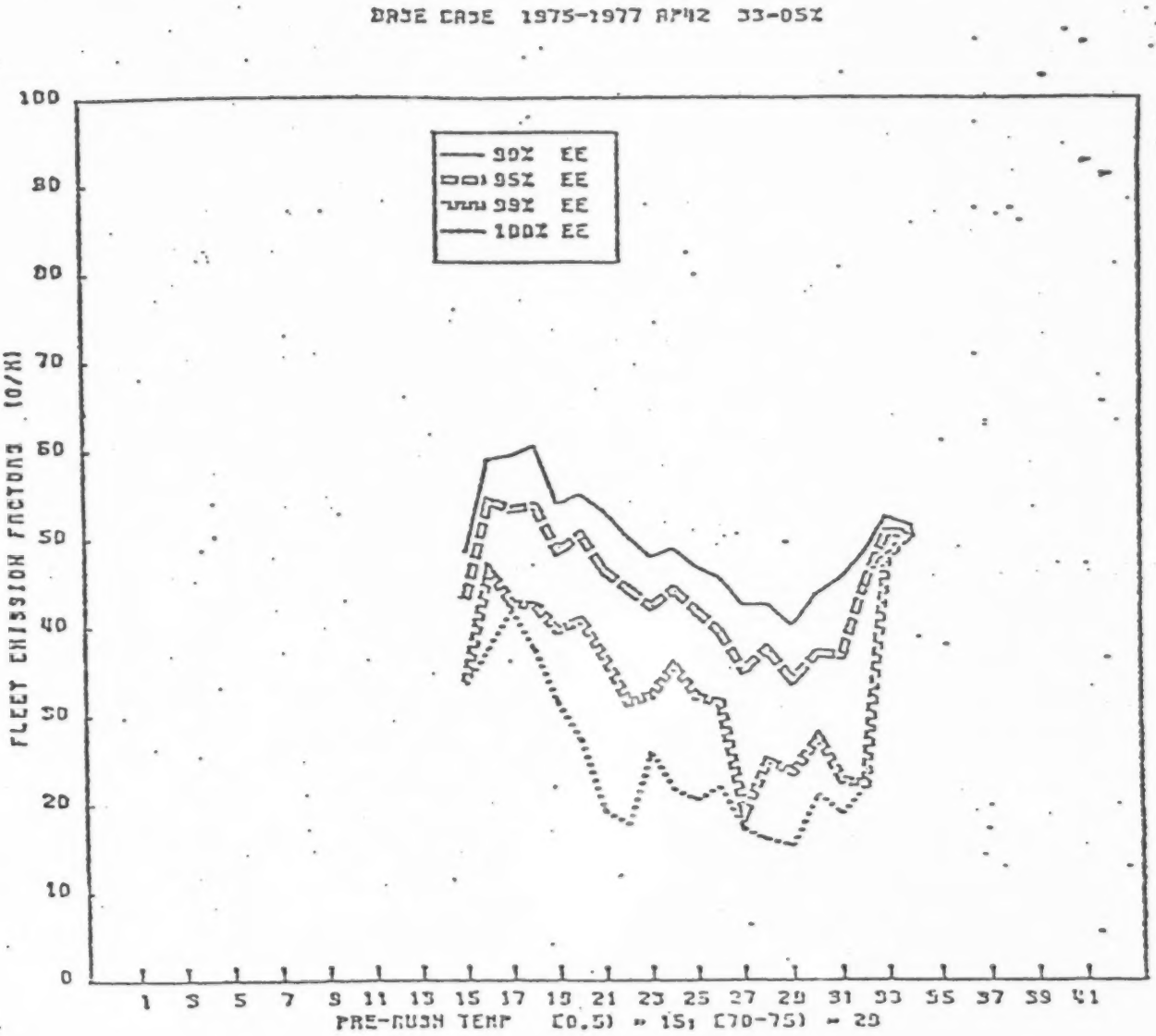


FIGURE A-5

MOBILE 2

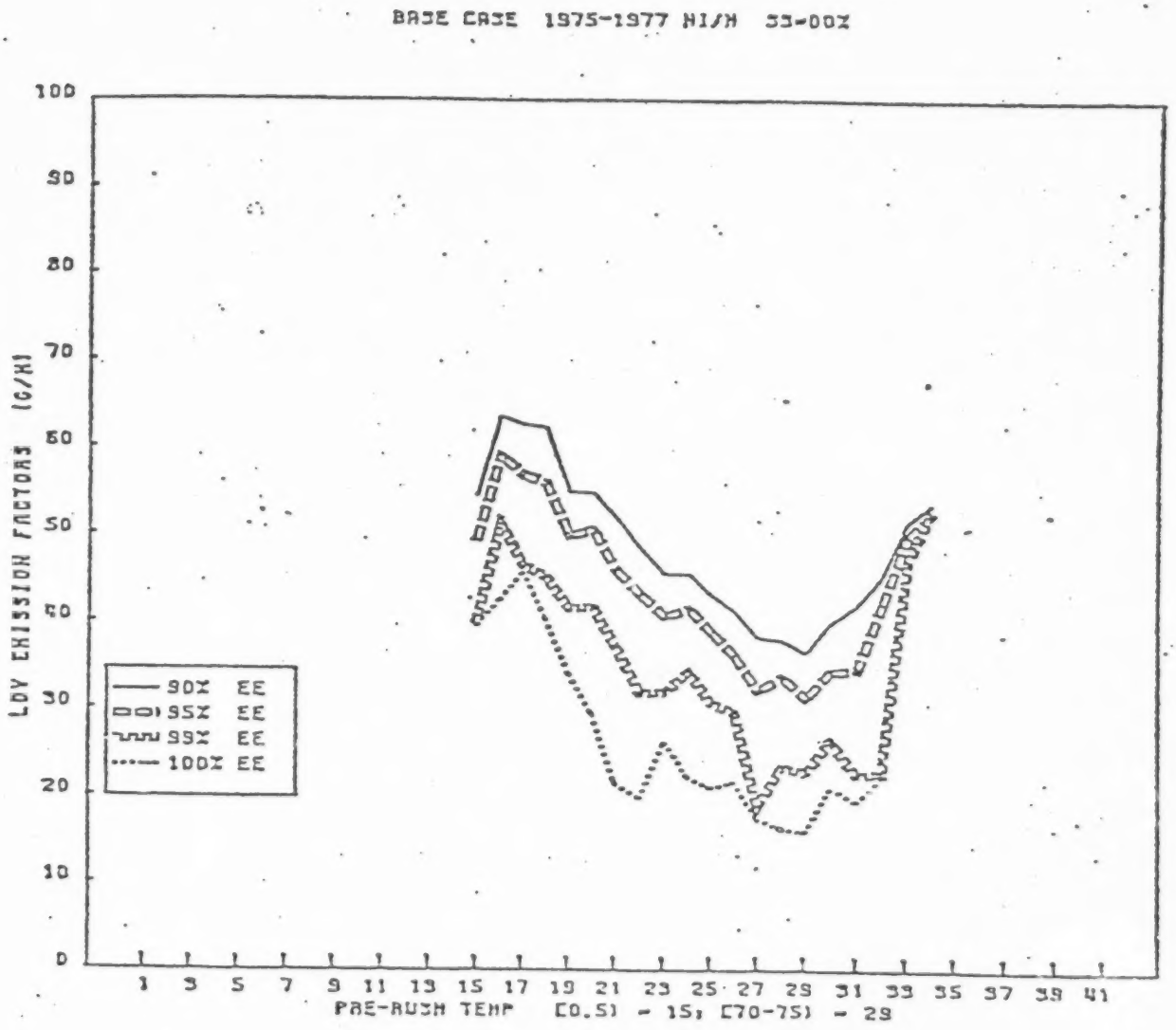


FIGURE A-6

MOBILE 2

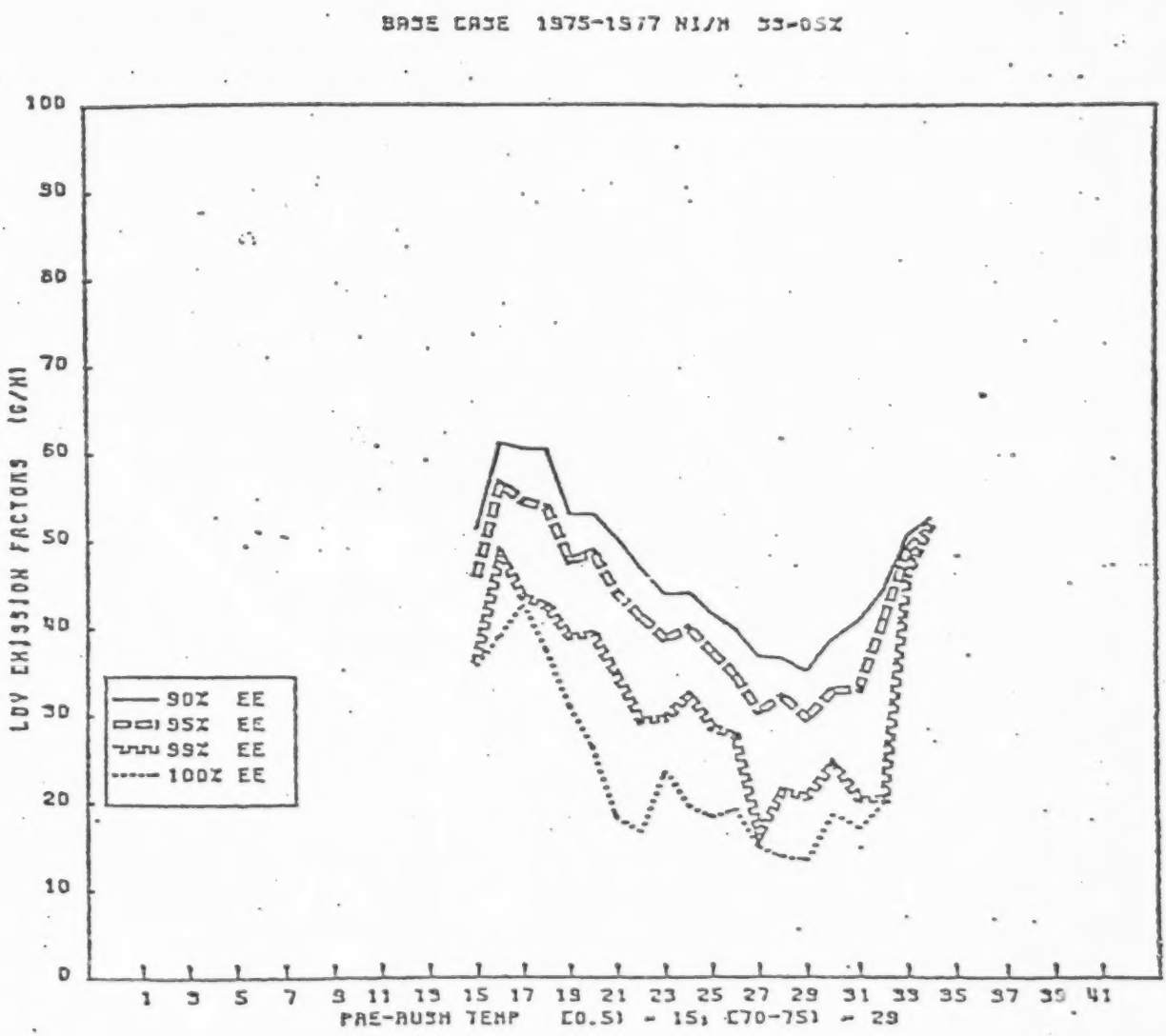


FIGURE A-7

MOBILE 2

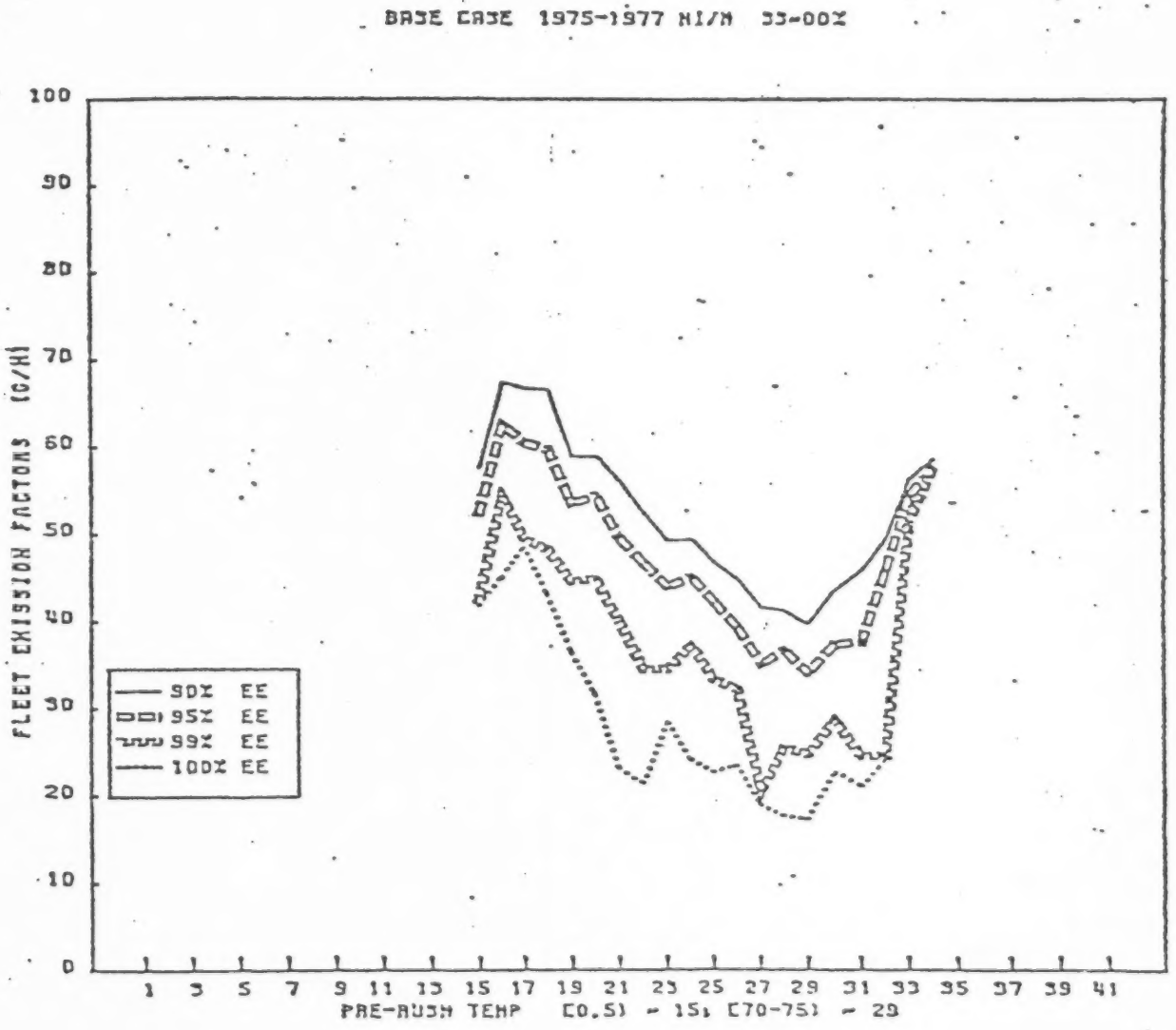


FIGURE A-8

MOBILE 2